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January 1998

US Army Corps
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Waterways Experiment
Station

Ship Navigation Simulation Study, Jacksonville Harbor, St. Johns River, Florida

Volume I: Main Text and Appendix A

by Randy A. McCollum, Jose A. Sánchez, Lisa C. Roig

WES

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Prepared for U.S. Army Engineer District, Jacksonville

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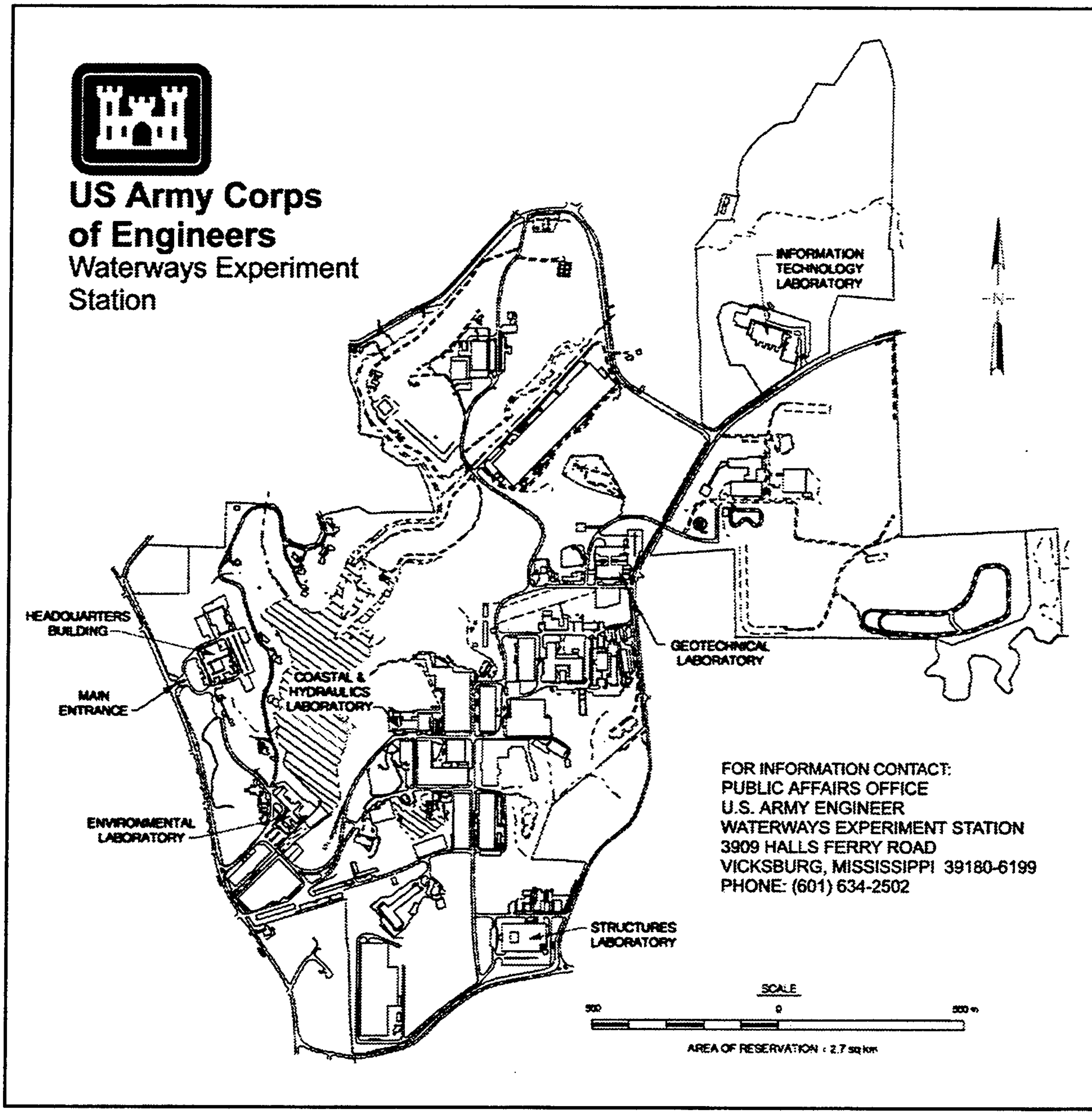

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Contents

[1] A limited number of copies of Appendix B were published under a separate cover. Copies will be furnished to qualified agencies upon request, as this appendix contains proprietary material.

Preface

The model investigation reported herein was conducted for the U.S. Army Engineer District, Jacksonville, by personnel of the Hydraulics Laboratory (HL) of the U.S. Army Engineer Waterways Experiment Station (WES) during the period September 1994 to March 1996.

The investigation was conducted under the general supervision of Messrs. Frank A. Herrmann, Jr., Director (retired), HL; Richard A. Sager, Acting Director, HL; and Robert F. Athow, Acting Assistant Director, HL.

The main text of this report was prepared by the principal investigator, Mr. Randy A. McCollum, Simulation Group, Navigation Division, HL. The study was under the immediate supervision of Dr. Larry L. Daggett, Chief, Navigation Division. Mr. McCollum was assisted by Mmes. Donna Derrick and Peggy Van Norman, Simulation Group.

The hydrodynamic and sediment transport numerical modeling investigation reported in Appendix A was conducted by Dr. Lisa C. Roig, Hydro-Science Division, and Mr. Jose A. Sanchez, Estuaries Branch, Waterways and Estuaries Division, under the direction of Mr. William H. McAnally, Chief, Waterways and Estuaries Division, and Dr. Robert T. McAdory, Jr., Chief, Estuaries Branch. Appendix A was prepared by Mr. Sanchez and Dr. Roig.

During the course of the model study, representatives from the Jacksonville District visited WES to observe the ship simulator operation and discuss plans to be examined and results of these examinations. The Jacksonville District was kept informed of the progress of the study through monthly progress reports and transmittal of a draft report at the completion of the study.

This report is being published by the WES Coastal and Hydraulics Laboratory (CHL). The CHL was formed in October 1996 with the merger of the WES Coastal Engineering Research Center and Hydraulics Laboratory. Dr. James Houston is the Director of the CHL, and Messrs. Richard A. Sager and Charles Calhoun, Jr., are Assistant Directors.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander was COL Robin R. Cababa, EN.

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Conversion Factors, Non-SI to SI Units of Measurement

Non-SI units of measurement used in this report can be converted to SI units as follows:

Multiply	By	Obtain
cubic feet	0.02832	cubic meters
degrees (angle)	0.01745329	radians
feet	0.3048	meters
horsepower (550 foot-pounds force per second)	745.6999	watts
knots (international)	0.5144444	meters per second
miles (U.S. nautical)	1.852	kilometers
miles (U.S. statute)	1.609347	kilometers
pounds force per second per square foot	47.88	pascals per second
slugs (mass) per cubic foot	515.4	kilograms per cubic meter

1 Introduction

Background

St. Johns River and Jacksonville Harbor are located on the eastern shoreline of Florida, approximately 25 miles[1] south of the Florida-Georgia state boundary (Figure 1). The authorized navigation channel in the St. Johns River extends from the entrance channel through the entrance jetties, then approximately 20 miles to downtown Jacksonville.

A variety of vessels visit the docks and terminals along the channel. Typically these vessels are bulk carriers, car carriers, tankers, and container ships. The largest vessels commonly using the channel are 950-ft by 106-ft container ships and 750-ft by 106-ft tanker/bulk carrier ships. The maximum working draft for these vessels is normally 36 to 38 ft.

Existing Conditions and Navigation Problems

The present authorized channel is maintained at 38 ft mean low water (mlw) (Figure 2). Figures 3 through 5 show the names of the various reaches and the buoy numbers. Channel widths vary from 400 ft in the inner reaches to over 1,000 ft in the Mayport Cut Range. Two-way traffic is permitted in most of the reaches but is restricted for large vessels in some of the narrower reaches during peak tidal currents. Outbound traffic has no draft restrictions due to tidal currents. Inbound traffic is restricted to a maximum of 30-ft draft during peak ebb tides.

Proposed Improvements

The U. S. Army Engineer District, Jacksonville, and the Jacksonville Port Authority are considering deepening the 38-ft maintained channel to 40 to 42 ft mean low water. Since the ship simulation model provides a reliable variance of ±2 ft, the requested ±42-ft ship simulation depth gives an adequate range of

[1] A table of factors for converting non-SI units of measure to SI units is found on page vii.

values for optimization of a selected depth based on benefits and environmental analyses. In most areas, deepening of the channel would be accomplished by extending the existing channel side slopes to a depth of 42 ft, thereby reducing the bottom width by 40 ft in areas of assumed side slope of 1V on 5H and by 24 ft in areas of assumed side slope of 1V on 3H. The proposals would also consider channel width increases for the critical reaches of Dames Point-Fulton Cutoff and Training Wall, along with channel realignment in the area of St. Johns Bluff Reach. A turning basin is also proposed for the intersection of the Terminal and Long Branch Reaches where docking pilots presently turn vessels in an unmaintained area.

Purpose and Scope

The ship simulator investigation will develop a safe and optimal navigation channel by examining the existing conditions along with the proposed channel improvements to determine the relative difficulty and safety of operation for each condition.

The study limits of the St. Johns River simulation were from approximately 3 miles outside the entrance jetties to the end of the maintained 38-ft channel in downtown Jacksonville, a distance of approximately 23 nautical miles. Also included was the Blount Island Channel on the west end of Blount Island. The initial plans examined were as follows:

a. Existing conditions (38-ft channel).

b. Plan A channel (42-ft depth with no channel widening).

c. Plan B channel (42-ft depth with all reaches widened to at least 575 ft).

Turning maneuvers in the Long Branch-Terminal Channel intersection (Figure 5) and from the Dames Point-Fulton Cutoff Reach into and out of the Blount Island Channel were performed by docking pilots.

2 Data Development

Description of Simulator

It is beyond the scope of this report to describe other than briefly the U.S. Army Engineer Waterways Experiment Station (WES) ship simulator ("Hydraulic design of deep draft navigation channels" 1989). The WES ship simulator provides the essential factors necessary in a controlled computer environment to allow the inclusion of the man-in-the-loop (local ship pilots) in the navigation channel design process. The simulator is operated in real-time by a pilot at a ship wheel placed in front of a screen upon which a computer-generated visual scene is projected. The visual scene is updated as the hydrodynamic portion of the simulator program computes a new ship position and heading resulting from manual input from the pilot (rudder, engine throttle, bow and stern thruster, and tug commands) and external forces. The external force capability of the simulator includes effects of wind, waves, currents, banks, shallow water, ship to ship interaction, and tugboats. In addition to the visual scene, pilots are provided simulated radar and other navigational information such as water depth, relative ground and water speed, magnitude of lateral vessel motions, relative wind speed and direction, and heading.

Required Data

Data required for the simulation study included channel geometry, bottom topography, channel currents for proposed as well as existing conditions, numerical models of design ships, and visual data of the physical scene in the study area. Dredging survey sheets provided by the Jacksonville District were used for establishing channel alignment. Current data were obtained from a TABS-2 finite element numerical model of the St. Johns River Channels developed for hydrodynamic and sedimentation studies (Appendix A). A reconnaissance trip was carried out to observe actual shipping operations in the study area. Still photographs were taken during the reconnaissance transits to aid in the generation of the simulated visual scene. Discussions with pilots were also held during this trip so WES engineers could become more familiar with concerns and problems experienced during channel operations.

Test File

The test file contains initial conditions (ship speed and heading, rudder angle, and engine setting) for the simulation and geographical coordinates for the channel alignment. The channel is defined in terms of cross sections located to coincide with changes in channel alignment and current direction and magnitude. The information used for the development of the St. Johns database was obtained from the District's project drawings and dredging surveys. The Florida state plane coordinate grid was also plotted on these drawings and was used for the simulator database coordinate system. Also included in the test file are the steepness and overbank depth (water depth at the top of the side slope) adjacent to the channel. These data are used by the computer to calculate bank effect forces on the design vessels. Specifications of other external forces such as wind are also included in this file. For this study the wind was established to be from the northeast at 35 knots and was set to be constant in both direction and magnitude. For the docking and turning maneuvers, the wind was set at 15 knots. There was no sheltering from wind effects anywhere in the study area.

For the St. Johns project, the simulator channel cross sections were placed approximately 500 ft apart except where the bends occurred or where channel width changed. Since the channels were fairly uniform, the simulator cross sections did not vary in spacing significantly. The simulator program handles the transition between cross sections on an interpolative basis.

Water depths for the simulator were based on authorized project depths. For the simulated existing channel, the water depth represented the existing condition taken from the most recent dredging survey furnished by the District. Also, bank slopes and overbank depths were obtained from the May 1993 District dredging survey. These data were used in the calculation of ship hull bank forces. Bank forces occur when a ship travels close to a submerged bank, wall, or docked ship, and the resulting effect is characterized by a movement toward the bank and a bow-out rotation away from the bank.

Scene File

The scene database comprises several data files containing geometrical information enabling the graphics computer to generate the simulated scene of the study area. The computer hardware and software used for visual scene generation are separate from the main computer of the ship simulator. The main computer provides motion and orientation information to a stand-alone graphics computer for correct vessel positioning in the scene, which is then viewed by the pilot. Operators view the scene as if they are standing on the bridge of a ship looking toward the bow of the ship in the foreground.

Aerial photographs, navigation charts, and dredging survey charts provided the basic data for generation of the visual scene. The simulations required low visual resolution beyond the immediate vicinity of the navigation channel. All land masses in the vicinity of the navigation channel were included in the scene. All aids to navigation in the vicinity of the study area were included. In addition to the man-made and topographical features in the vicinity, the visual scene included a perspective view of the bow of the ship from the pilot's viewpoint, along with the ability to see an oncoming vessel in meeting and passing situations. Visual databases for all design ships were developed at WES.

Radar File

The radar file contains coordinates defining the border between land and water and significant man-made objects, such as docked ships and aids to navigation. These data are used by another graphics computer that connects the coordinates with straight lines and displays them on a terminal. The objects viewed are composed of visual information that simulates shipboard radar. The main information sources for this database were the project drawings and dredging survey sheets supplied by the District.

Ship Files

The ship files contain characteristics and hydrodynamic coefficients for the design vessels. These data are the computer's definition of the ship. The coefficients govern the reaction of the ship to external forces, such as wind, current, waves, banks, underkeel clearance, and ship/ship interaction, and internal controls, such as rudder and engine revolutions per minute (rpm) commands. The numerical ship models used for the existing and plan condition tanker/bulk carriers for the St. Johns Harbor simulations, selected from the inventory of available ship models, were developed by Tracor Hydronautics, Inc., of Laurel, MD (Ankudinov 1988, 1989). The existing condition container ship, selected from the available ship model inventory, and a new container ship developed for the design container vessel for the plan conditions were developed by Designers and Planners, Inc., of Arlington, VA (Ankudinov 1993, 1995). The design ships were chosen based on the District's economic analysis of future shipping business and operations.

The design ships for the simulation of St. Johns Harbor with existing conditions were a 950-ft by 106-ft container ship and a 750-ft by 106-ft tanker/bulk carrier for the existing conditions. The design vessels for the proposed channel conditions were a 984-ft by 122-ft container ship and an 855-ft by 106-ft tanker/bulk carrier. The tankers were set to always be inbound and the container ships were always outbound. For the existing condition tanker with ebb tide the draft was restricted to 32 ft. For the existing condition tanker with flood tide and the container ship for both tidal conditions the draft was set at 36 ft. For the proposed channel, the inbound tanker was set to draft with ebb tide at 36 ft and with flood tide at 40 ft. The design container ship for the proposed channel was set to always draft 40 ft.

Current File

The current file contains current magnitude, current direction, and water depth for eight points across each cross section defining the channel alignment. Current data for a ship simulation study are usually obtained from physical or numerical models. In this study, current data were available from a numerical model of St. Johns Harbor (Appendix A). The model bathymetry was modified for generation of currents for the proposed channel conditions.

Currents were used for the maximum spring ebb and flood tides. The peak flood currents were taken from the TABS model for the tidal cycle between hours 61 and 63, and the peak ebb currents were taken from the tidal cycle between hours 67 and 69. Currents as used for the existing channel conditions for the ebb and flood tides are presented in Plates 1 and 2 (Appendix B).[1]

Operation Conditions

The operation scenarios, design vessels, and environmental conditions were selected in order to examine the existing and proposed channels in the "maximum credible adverse situation," that is, the worst conditions under which the harbor would maintain normal operations. This approach provides a built-in safety factor when analyzing the results. The existing channels were examined to provide a base with which to compare operations conducted in the proposed channels and to provide a basis for comparison of conditions by the pilots involved in the study.

DGPS Ship Tracking

As part of the development of data for the study reach, a survey of existing navigation practices was performed using a Differential Global Positioning System (DGPS). When performing a DGPS, a base station is established consisting of a DGPS receiver located at a survey control point. Two DGPS receivers are set up on the ship at measured points, usually near the bow and the stern of the ship. The three DGPS receivers simultaneously record data at the same rate during the transit of the vessel. Satellite data is updated in the DGPS receiver every second; however, recording the position of the vessel every second is unnecessary and would require a large amount of receiver memory for data storage if the vessel is tracked for several hours. Recording the position of the mobile receivers every 5 to 15 sec has been sufficient for evaluation of vessel paths. The data from each mobile DGPS receiver is post-processed using information from the base station to obtain accurate positioning of the mobile

[1] All plates are included in Appendix B. A limited number of copies of Appendix B were published under a separate cover due to proprietary data. Copies will be furnished to qualified agencies upon request.

receiver. The positions of the two mobile receivers are then used to plot the path, speed, and orientation of the vessel relative to the navigation channel.

The DGPS tracks of recorded vessel movements are presented in Plates 3-10 (Appendix B). The tracks indicate that the existing channel appears to provide adequate width for the vessels being tracked for most reaches. It appears that extra width in the Training Wall Reach might be beneficial due to the number of tracks that go near to the channel limits along the southwest side of the channel. None of the tracks used the southernmost half of the St. Johns Bluff Reach, an area of considerable bank erosion problems. None of the DGPS tracks indicate that the proposals for either Plan A or Plan B would cause any navigation concerns, except for the proposed narrowing of the Training Wall Reach with Plan A, an area where the DGPS plots indicate a possible need for additional channel width. Realignment of the St. Johns Bluff Reach would appear to better align the channel to the track the pilots routinely use.

3 Navigation Study

Validation

The simulation was validated with the assistance of two pilots licensed for St. Johns River. The following information was verified and fine tuned during validation:

a. Wind effects.

b. Bank conditions.

c. Currents.

d. Ship engine and rudder response.

e. The visual scene and radar image of the study area.

(1) Location of all aids to navigation.

(2) Location and orientation of the docks.

(3) Location of structures visible from the vessel.

Validation began by the pilots maneuvering through the visual scene in a fast-time model in order to quickly check building and buoy locations. Then real-time simulation runs were undertaken with the vessel transiting the entire study area. The pilot gave special attention to the response of the ship due to external forces. Problem areas were isolated, and the prototype data for these areas were examined. The model was then adjusted and further simulation runs were undertaken through the problem areas; if necessary, additional adjustment was made. This process was repeated until the pilot was satisfied that the simulated vessel response was similar to that of an actual vessel in the prototype.

Preliminary Studies

In order to optimize the channel design used for final evaluation, two licensed pilots came to WES to perform operations with two preliminary channel designs.

Plan A

Plan A involves dredging the entire channel from 38 to 42 ft by extending the existing side slopes to the new depth which decreases the channel width from 24 ft to 40 ft (Figure 6).

Plan B

Plan B dredges the entire channel as described for Plan A but also widens all the channel reaches to at least a 575-ft width (Figure 7). Operations performed with the Plan A channel design indicated that additional width was needed in certain areas such as Dames Point-Fulton Cutoff and in the Trout River Cut. Operations with the Plan B channel design indicated that widening the inner channels to 575 ft did not significantly impact the way they made their transits; i.e., they still used the same track as with the narrower channels. The results of piloted runs for Plans A and B led to the development of Plan C for full simulation evaluation.

Plan C

The modifications made for Plan C (Figure 8) versus the existing conditions (Figure 2) are as follows:

a. Dredging the channel to 42 ft, extending the existing side slopes to the new depth, effectively narrowing the bottom width by 24 ft to 40 ft, according to the position along the channel.

b. Widening the Training Wall Reach to a minimum 575-ft bottom width.

c. Realigning the St. Johns Bluff Reach and moving the navigation channel north, away from the bluff.

d. Widening the Dames Point-Fulton Cutoff Reach to a 575-ft bottom width.

e. Widening Trout River Cut Range to a 450-ft bottom width.

f. Realigning the inside of the Chaseville Turn where it joins the Trout River Cut Range.

g. Providing a turning basin at the northeast corner of the junction of the Terminal and Long Branch Ranges.

Trial Scenarios

Investigation conditions

The trial scenarios, design vessels, and environmental conditions were selected to examine the existing and proposed channels in the "maximum credible adverse situation," that is, the worst conditions under which the harbor would maintain normal operations. This approach provides a built-in safety factor when analyzing the results. The existing channels were examined to provide both a base to compare experiments in the proposed channels and a basis for comparisons of conditions by the simulation pilots. The proposed channels used the same bank conditions as the existing channel.

For the existing channel runs, all the channel reaches were defined as a minimum of 38 ft deep, assuming any shoaled areas would be dredged to the authorized channel width and depth. The plan channel was defined as a minimum of 42 ft deep.

Procedures

Trials were conducted in a random order to prevent prejudicing the results as would happen if, for example, all existing conditions were run prior to running the plans. The skill the pilots gained by operating the simulator could cause the plans to look easier than they actually are.

During each run, the characteristic parameters of the ship were automatically recorded every 10 sec. These parameters included the position of the ship's center of gravity, speed, engine rpm, heading, drift angle, rate of turn, rudder angle, and port and starboard clearances.

To determine the docking pilots' ability to turn vessels in the proposed turning area and in the Blount Island Channel, a series of real-time simulations were performed. During these runs, the vessel was started approximately 0.5 mile outside the turning basin, and the docking pilot was asked to take the vessel into the basin and turn. The docking pilots were provided up to three 3,000-horse power (hp) tugs to assist the turn. The runs were performed with both maximum ebb and maximum flood tides with the existing turning area and the proposed maintained basin. For the turns into and out of the Blount Island Channel, the docking pilots were asked to start approximately 0.5 mile outside the junction of the Blount Island Channel with the Dame Point-Fulton Cutoff Reach and complete the turn. The pilots used the same tidal conditions as with the turning basin runs and were allowed three 3,000-hp tugs.

To study all channels with a variety of meeting and passing scenarios, the study area was divided into five reaches, A through E. Study of two-way traffic was accomplished with two real-time piloted simulations conducted simultaneously. The pilots were in verbal contact with each other and could see the other vessel on their visual scene and radar display.

Trial reaches

Reach A. The inbound pilot started approximately 1 mile outside the entrance jetties, and the outbound pilot started just north of the Matthews Bridge in the Terminal Channel. The pilots were asked to transit the entire channel, meeting and passing each other somewhere near the Dames Point-Fulton Cutoff Reach.

Reach B. The inbound pilot started in the St. Johns Bar Cut Reach near the outer end of the entrance jetties, and the outbound pilot started in the Pilot Town Cut Range; they were to meet in the Bar Cut Reach. The runs were terminated shortly after meeting and passing was accomplished.

Reach C. The inbound pilot started in the Mile Point Turn, and the outbound pilot started in the Short Cut Turn; they were to meet in the Training Wall Reach. The runs were terminated shortly after meeting and passing was accomplished. Runs were performed only with flood tide conditions.

Reach D. The inbound pilot started in the Short Cut Turn, and the outbound pilot started in the eastern end of the Dames Point-Fulton Cutoff Reach; they were to meet in the White Shell/St. Johns Bluff Reaches. The runs were terminated shortly after meeting and passing was accomplished.

Reach E. The inbound pilot started at the eastern end of the Dames Point-Fulton Cutoff Reach, and the outbound pilot started in the western end of the Dames Point-Fulton Cutoff Reach; they were to meet approximately mid-way of the reach. The runs were terminated shortly after meeting and passing was accomplished.

Mill Cove Plan 5 was developed in the hydrodynamic and sediment transport numerical model study (Appendix A). For runs with the Mill Cove Plan 5 currents, the pilots performed meeting and passing using the Reach E scenario. The pilots were also asked to perform one-way passages going inbound and outbound between the Trout River Reach to the Long Branch Reach.

4 Study Results

Two professional docking pilots performed turning maneuvers for the Blount Island Channel/Dames Point-Fulton Cutoff Channel and for the turning area at the junction of the Long Branch and Terminal Channels. Four professional pilots from the St. Johns Bar Pilots Association participated in the simulations of the previously listed trial reaches of the St. Johns River Project. The primary methods of analysis for the results of the simulation runs, are pilot run evaluations, final questionnaires, analysis of vessel control parameters, and visual inspection of recorded track-lines.

Pilot Evaluations

After completing each run condition, the pilot was asked to complete an evaluation of the run, rating the bank effect, wind effects, current, ship handling, and simulator realism. For the questions concerning ship handling and environmental effects, the pilot was asked to assume that a value of "5" would be a typical rating for a real life condition and should rate the simulation according to how he believed it responded in relation to that (a rating less than 5 being less difficult than typical and higher than 5 being more difficult than typical). For the question of simulator realism, the pilot was asked to rate each individual run from 0-10 with 0 equivalent to very poor and 10 as excellent.

The ratings of each question for each scenario were averaged, and then the value of 5 (the rating for "typical") was subtracted from the averages. These values were then plotted in the form of a bar chart set up so that the typical value of 5 on the rating form would yield a value of 0 on the plot. This allows direct comparison of the same question for plan condition and operation mode and also provides a better means to examine how the individual ratings based on the simulator operation corresponded to the pilots' experience of what would be "typical."

The plots of the averaged pilots' ratings are presented in Figures 9-34. The ratings for simulator realism for each run were totaled and averaged to provide a more quantitative value of overall simulator realism based on the individual runs as compared with the more qualitative overall evaluation of the simulator as asked for during the final debriefing questionnaire.

Jetties to Matthews Bridge

Inbound, ebb tide. For all questions concerning ship handling, the Plan C channel condition rated as the same or less difficult than the existing conditions (Figure 9).

Outbound, ebb tide. For most questions, the Plan C channel condition rated slightly more difficult than the existing condition (Figure 10). The differences in ratings are 0.5 or less, so statistically the ratings are almost identical.

Inbound, flood tide. For the questions of difficulty, current effect, bank effect, wind effect, and attention required, the existing channel was rated significantly more difficult (Figure 11). For the questions of danger of grounding and meeting and passing difficulty, the pilots rated the Plan C channel as significantly higher in difficulty. Why the pilots rated meeting and passing and danger of grounding as more difficult with the plan condition and rated overall difficulty and environmental effects to be less difficult is not discernable.

Outbound, flood tide. For all questions, except meeting and passing difficulty, the pilots rated the existing channel to be more difficult than the Plan C channel (Figure 12). The difference in value for the meeting and passing of the existing condition to Plan C is relatively large. Why the pilots rated the meeting and passing more difficult with the Plan C channel after rating the overall difficulty of the run to be less is not clear.

St. Johns Bar Cut, meeting and passing

Inbound, ebb tide. The pilots rated all the questions except attention required for the existing conditions to be more difficult than the Plan C channel (Figure 13). The ratings for attention required were approximately the same for each condition.

Outbound, ebb tide. The pilots rated all questions except for attention required and bank effects as more difficult for the existing condition than the plan condition (Figure 14). The slightly higher rating for bank effect for the plan channel may have precipitated the higher value for attention required.

Inbound, flood tide. The ratings for the existing channel and the Plan C channel were almost identical for all questions except for current effect (Figure 15). The pilots apparently perceived little difference between the two plans.

Outbound, flood tide. The Plan C channel was rated significantly more difficult for most of the questions asked (Figure 16). The pilots rated the existing channel to be very near their typical experience, except for bank effects. Although the plan channel is rated as more difficult, the overall rating for difficulty of run was almost the same as with the existing channel.

Training Wall Reach, meeting and passing

Inbound, flood tide. The existing condition was rated the same or more difficult than the Plan C condition for all questions (Figure 17).

Outbound, flood tide. The existing channel condition was rated the same or more difficult for all questions except for bank effects (Figure 18). The lower ratings of difficulty of run, danger of grounding or striking an object, and meeting and passing for Plan C versus the existing condition indicate improvement over the existing conditions.

St. Johns Bluff Reach, meeting and passing

Inbound, ebb tide. The ratings for all questions were more difficult for the Plan C channel than the existing condition (Figure 19). This may be a reflection of the new channel alignment in this reach and the pilots' unfamiliarity with the new alignment.

Outbound, ebb tide. The existing channel rated significantly more difficult for all questions for the existing condition versus the Plan C conditions (Figure 20). The large differentials between the ratings for most of the questions appear to indicate a significant improvement with Plan C.

Inbound, flood tide. The existing condition rated more difficult for all questions (Figure 21). The differentials of the ratings for attention required, danger of grounding, and meeting and passing difficulty would indicate a perception of significant improvement in the Plan C channel design.

Outbound, flood tide. The ratings for the Plan C channel were the same or more difficult for all questions (Figure 22). Since the differential of the ratings for most questions was small, it appears that there is little difference between either of the conditions.

Dames Point-Fulton Cutoff Reach, meeting and passing

Inbound, ebb tide. The ratings for the existing condition was the same or more difficult than the Plan C conditions (Figure 23). The ratings suggest a modest improvement with the Plan C channel.

Outbound, ebb tide. The questions of difficulty of run, current effects, bank effects, and danger of grounding are rated slightly less difficult with Plan C with the remaining questions being the same or slightly more difficult with the existing condition (Figure 24). Since the rating differentials are relatively small, it appears that there is little difference between the two channel conditions.

Inbound, flood tide. The existing channel is rated more difficult for all questions than the Plan C channel, indicating that Plan C is significantly better than the existing conditions (Figure 25).

Outbound, flood tide. Plan C was rated slightly more difficult for most of the questions than was the existing channel, but not by a large differential (Figure 26). The ratings indicate that Plan C is slightly more difficult for this direction and tide condition.

Dames Point-Fulton Cutoff, meeting and passing, Mill Cove Plan 5

Inbound, ebb tide. All questions rated the Plan C channel without the Mill Cove Plan 5 to be almost the same as the Plan C channel with the Mill Cove Plan 5, indicating no significant differences with either plan (Figure 27).

Outbound, ebb tide. The ratings for most of the questions were almost identical for both plans (Figure 28). It appears that there are no significant differences noticed with either plan.

Inbound, flood tide. All the questions, except for meeting and passing difficulty, were rated more difficult for the Plan C Channel with the Mill Cove Plan 5 (Figure 29). This indicates some increased difficulty with this plan.

Outbound, flood tide. Again, most questions were rated almost the same with either plan condition, indicating no significant differences (Figure 30).

Trout River Cut, Mill Cove Plan 5

Inbound, ebb tide. The pilots rated the current effect, wind effect, attention required, and danger of grounding for the Plan C Channel with Mill Cove Plan 5 to be significantly higher than the same channel design without the Mill Cove Plan 5 (Figure 31). This indicates some increased difficulty of navigation, although the overall difficulty of the runs with and without the Mill Cove Plan was about the same.

Outbound, ebb tide. All questions were rated as more difficult with Mill Cove Plan 5 (Figure 32). The large differentials for difficulty of run, current effect, attention required, and danger of grounding suggest a large increase of difficulty with the Mill Cove plan.

Inbound, flood tide. All questions except for wind effect were rated more difficult for the Plan C channel without the Mill Cove Plan 5 (Figure 33). This suggests a slight improvement using the Mill Cove plan.

Outbound, flood tide. All questions were rated more difficult using the Mill Cove Plan 5 (Figure 34). This suggests some increased difficulty when using this plan.

The overall average of simulator realism as taken from the individual run evaluations was 6.67. Perfect realism would be rated at 10.0. This average indicates that the simulation is not absolutely realistic, but does provide a reasonably high degree of realism that provides confidence that the results are reliable.

Final Questionnaires

After finishing all of the simulation scenarios, the bar pilots completed a final questionnaire to give their opinions on the project as well as the simulation. The comments made by the pilots are as follows:

1. What is your impression of the Plan C channel design? Could this channel design lessen some of the draft restrictions during ebb tide?

"I feel the Plan C channel design is inadequate in that it does not widen the narrow channels up river of Dames Point; in particular: Trout River Cut, Drummond Creek Range and Brills Cut. I realize that to widen Trout River Cut is a real problem. As it is now, traffic is restricted to one-way in that narrow channel. With a large tanker at either Steuart Oil Terminal and/or the Navy Fuel Dock it requires a very careful highly skilled maneuver to transit that area with a large vessel in clear weather, not to mention fog or a heavy rain squall. In Plan C, buoy 69 is moved allowing a better passage by Steuart. That is good but some of the shoal area behind buoy 71 if removed, widening the area by even 100 feet would make for a safer turn outbound with an ebb current. The Shell Oil dock opposite #71 was demolished by an outbound ship years ago in clear weather. Also a poor handling outbound container ship collided with a tanker at Steuart in the 70's after turning buoy 71."

"Downriver of Dames Pt., Plan C shows buoy 34 further north with a widening in that direction but narrowing the channel on the south which is not good as ship and or tows (Crowley Barges of 730' on a 500' long hawser are towed in and out regularly, as well as other large barges) meet there. The docking masters use that area as a turning basin for the 947' military ships based in the nearby Gate Petroleum slip. It is also the only area downriver of the Tallyrand Terminal where a vessel can, with some degree of safety, be anchored in fog or an emergency."

"All in all I'm in favor of the deepened channel. However for the 1000' LOA × 40' draft vessels such as those simulated, an increase in restrictions, i.e., meeting, passing, etc. would be more likely than a reduction."

"The Plan C design is a very functional and workable situation. It is doubtful that it would affect the ebb restrictions. Cross currents at the Intracoastal Waterway intersection remain significantly heightened by the ebb."

"The Plan C design appears to allow the modeled vessel to proceed safely with the same restrictions that are currently in place for current and tide. I do not feel that it would be prudent to relax the restriction on vessels over 32 feet without observation of the actual completed project. Our ability to successfully negotiate the river with vessels in excess of our current limits in the simulation is mostly due to the fact that the limits of the current were known. This is not the case in the actual river."

2. Will the proposed limitations of meeting and passing areas significantly impact operations?

"The proposed limitations of meeting and passing areas would further impact operations, particularly for large vessels. Example: The Sea-Land Atlantic class vessels (949' x 105') normally do not meet other large vessels between Mayport (buoy 18) and upriver to White Shell's Cut (buoy 27)."

"No. Meeting and passing areas will remain essentially the same."

"I don't think that they would. Given the length and characteristics of the St. Johns River, I don't see where the proposed limitations would be significantly less convenient than current standard practice. At the same time an increase in channel depth and the addition of a turning basin could significantly increase the tonnage coming into Jacksonville and keep the port competitive."

"No. I do not feel that the operation of vessels on the river will change all that much with the exception of the allowable depth. It is likely that the larger and deeper vessels will continue to meet and pass in the most favorable places."

3. What is your opinion of the changes proposed for Mill Cove and how will it affect your operations?

"Our operations would not be affected by changes in currents (as portrayed in the model) caused by the Mill Cove proposal. However, siltation and resultant shoaling could affect river operations."

"It appears that the changes in Mill Cove will make future operations on the river easier. The reduction of cross-current in three critical areas will allow increase use of these areas (Dames Point-Fulton Cutoff and Drummond Creek Range: Increase use of these two areas; Trout River Cut will still be one-way traffic) for meeting and passing."

4. Do you have any suggestions to improve navigation of the proposed channel (alignment, channel width, navigation aids, etc.)?

"A) Refer to the answers for question #1 for widening upriver of Dames Point. Presently vessels mostly avoid meeting in Short Cut Turn. Widening it one hundred feet or more would allow for meeting of many vessels.

B) Widening Training Wall so that it could be one course (now 3 degrees difference between the upper and lower reaches) should be done. In Plan C, I don't think the widener is enough for that.
C) A range at the west end of Drummond Creek Range is really needed."

"My primary wishes are the same as they've always been, namely a widening of Drummond Creek Range Channel and Trout River Cut Channel. Also, there should really be inbound ranges for Drummond Creek Range."

"Increase the width of Drummond Creek Range (400 ft to 600 ft) and install ranges visible to inbound traffic."

"Check to see how the reduction of width in St. Johns Bluff will impact turning vessels of up to 1000 ft in that area. Bring the Federal Channel up to the edge of the terminal area at Blount Island."

5. Do you have any suggestions for improving the simulation?

"Yes, I think the simulation could be improved by: A) Put a mast or jack staff on the centerline forward on the tankers. B) The terrain is too flat. I am not saying make it realistic with buildings, etc. but make it more irregular as pilots look ahead most the time to judge the swing and rate of same. Most ships do not have swing indicators. I found myself using the radar and swing indicator a great deal more than I would in reality. The rate of swing appeared to increase too steadily, in most cases. In reality it picks up slowly and takes longer to check, particularly for a deep vessel, and then gradually increases in the other direction, even when using hard over rudder. I found myself using hard right and hard left a lot more than I normally would."

"Understanding, of course, that there are time and budget constraints, the imperfections that I thought warranted correction are as follows:
1. Visual depth perspective unrealistic: buoys appeared much closer than radar showed them. After learning this I made turns based 90% on radar and rate-of-turn indicator. Shipboard I do 90% of my turns based on visual input.
2. Vessel interaction between meeting vessels: Suction between the sterns of meeting vessels at any given distance was 5 to 10 times anything I've ever felt.
3. Rotational momentum underestimated: Rate of swing does not in reality increase steady between a swing to one side checked into a swing to the other side."

"Continued refinement of the visuals."

"The position of the bridge at Dames Point is just enough off to make the outbound passage difficult using only visual (big screen) cues."

6. On a scale of 0 to 10 (10 being excellent), what is your overall opinion of the simulator and of the St. Johns River/Jacksonville Harbor simulation?

"For what the simulator is intended to accomplish I feel it does a reasonably good job. I rate it and the St. Johns River/Jacksonville Harbor simulation a 7 ½ on a scale of 0 to 10."

"8. For the purpose for which it was designed it does a good job and I feel that to shoot for realistic simulation in every aspect would be at best unnecessarily time consuming and expensive; i.e., there is no reason to visually show the houses along the banks etc. Perhaps a not too difficult improvement would be to add an arbitrarily jagged horizon as an aid for judging swing visually. It isn't terribly important that high and low spots on the simulated horizon match actual topographical reality."

"8."

"9. There is always room for improvement. For the intended purpose the simulation is good and includes the defining characteristics of the river."

7. Comments:

"Our St. Johns River Channel needs to be modernized going into the 21st Century. Without widening Drummond Creek Range and Trout River Cut or making significant improvements to the latter, few if any, companies will want to commit large vessels (in excess of 800') to calling regularly at terminals upriver of Trout River Cut. This was one of the main reasons Sea-Land opted to move to Blount Island from the Tallyrand Terminal. This being the case, extensive dredging to make a turning basin as in Plan C may not be justified. However, one in the vicinity of Blount Island (or at least dredging south of the channel where the 950' ships are turned regularly, now in 1100' or less) and the newly proposed JPA Terminal just up river of Dames Point would be. Here again, I recommend the dockingmaster association be consulted."

"I was very impressed with the reliability of the simulator and peripheral systems. We worked 5 days without a single down time: A first in my experience with simulators. I would be happy to participate again in the future."

"The harbor project is one that I fully support from an operational standpoint. My experience with the simulator/model was positive and I commend all those who have a hand in the project."

"I think that everybody involved in this project had the ultimate goal of river improvement in mind while they were working on it. I hope that funding is found to complete the project and make these efforts worthwhile."

For the docking pilots, the questions were as follows:

1. What is your opinion of the proposed turning basin?

"The proposed turning basin is not large enough in a North/South direction to permit turning larger container vessels (980' x 120' with a draft of 40 feet) in a strong ebb current. In a strong flood current it is barely large enough."

"Any increase in depth and width would be an improvement."

2. Do the proposed channel modifications and use of a larger vessel into and out of the Blount Island Channel present any more difficulties than the existing channel design and current operating conditions?

"The proposed channel modifications and larger vessels transiting the area in and out of the Old River Channel from and to the Fulton-Dame Point Cutoff do not materially change the situation that presently exists for maneuvering vessels."

"No. Presently, large and/or poor handling vessels are handled at or near slack water."

3. Do you have any suggestions to improve navigation of the proposed turning basin and the Blount Island Channel (alignment, channel width, navigation aids, etc.)?

"I see no need to make any changes to the channel at the west end of Blount Island where the Old River Channel meets the Fulton Dame Pt. Cutoff. However, the two aids to navigation that are now maintained by Celotex Corp. (Q 12 ft Priv.) and the USCG (fl. G. 4s "1") need to be maintained in the future as a guide when making the turn into the Old River Channel. The proposed turning basin needs to be extended to the south to buoy "75" by removing the added buoy north of "75" and dredging a line between "75" and the other added buoy to the NE of "75." This additional length in a North/ South direction will make it possible to turn large deeply loaded vessels in a strong current."

"Turning Basin - No. B.I. Channel - B. I. Channel is only 300' wide and is presently "silting in." The channel width needs to be increased as much as possible."

4. Do you have any suggestions for improving the simulation?

"The simulation for ship handling purposes is quite good; however, the engine revolutions should increase and decrease more rapidly to more closely portray the characteristics of a diesel engine and not a steam turbine."

"The North and South Bridge spans should be added to the radar simulation."

5. On a scale of 0 to 10 (10 being excellent), what is your overall opinion of the simulator and of the St. Johns River/Jacksonville Harbor simulation?

"Overall the simulation is an 8."

"7."

6. Comments:

"I hope my testing was of benefit to this project, but I didn't feel I was familiar with the simulator until it was about time for me to leave."

Ship Parameter Plots

During each run, the control, positioning, and orientation parameters of the ship were recorded every 10 sec. These parameters included position, heading, port and starboard clearances, ship speed, engine speed in propeller revolutions per minute (rpm), and rudder angle. These statistical parameters were plotted against distance along track. Distance along track is calculated by projecting the position of the ship's center of gravity perpendicular to the center line of the channel and is measured from the beginning of the centerline (Figure 35). For reference purposes, the locations of important landmarks are identified. The plots for ship speed, engine rpm, and rudder usage are presented in Plates 11-36. Plots for port and starboard clearances are presented in Plates 37-62.

Parameter plots will not be presented for runs by the docking pilots. The vessels were mostly in the control of the tugs so usage of engine and rudder would not reveal any useful information. Calculation of clearance distance from a slowly moving, rotating vessel can be confusing since the vessel may actually track backwards along the trackline for a period of time as it rotates, causing starboard clearance to become port clearance after the vessel rotates more than 90 deg.

Speed, Engine RPM, and Rudder Position

Inbound, ebb tide. The runs from the entrance channel jetties to downtown Jacksonville show consistent speed and engine usage for both existing and plan conditions (Plate 11). The plots for rudder usage show that the pilots tended to use more rudder to make the turn under the Dame Point Bridge and in making the inner turns along the Drummond Creek and Trout River Reaches than with the existing condition. The plots for the other reaches (Plates 12-14) show similar speed and usage of engine and rudder for both existing and plan conditions, except for runs made with the Mill Cove currents (Plates 15 and 16). In these cases the pilots used less engine so they could better "feel" the current effects of the proposed changes to Mill Cove. This is also reflected in the drop in speed from the Plan C channel without the Mill Cove plan.

Inbound, flood tide. The runs from the jetties to downtown show that the pilots used much more engine power for the plan channel than the existing channel, which is reflected in both the rpm and speed plots (Plate 17). The pilots also used more rudder in making most of the turns throughout the run, but this may be due to the increased speed at which they were making the runs. This is especially evident as the pilots turned under the Dames Point Bridge. The average speed as they approached the bridge was approximately 15 knots for the plan channel versus about 10 knots for the existing channel. This is a major cause for the widespread use of near maximum rudder to complete the turn for the plan channel versus only about a peak of 60 percent of maximum rudder with the existing conditions. The plots for Reaches B, C, D, and E (Plates 18-21) show that speed, engine rpm, and rudder of the plan channel are consistent with that used for the existing channel. The only major difference was Reach D where the pilots tended to use a larger value of port rudder to make Short Cut Turn for the proposed channel than with the existing channel. For the runs using the Mill Cove currents (Plates 22 and 23), the pilots again tended to use less engine so they could "feel" the current effect. This did not appear to appreciably change the amount of rudder required versus the plan channel condition without the Mill Cove currents.

Outbound, ebb tide. The runs from downtown to the jetties show that the pilots used similar amounts of engine rpm for both the plan and existing channels but the speed for the plan channel was reduced (Plate 24). This is due to larger draft (40 ft versus 36 ft) and a larger vessel (984 ft by 122 ft versus 950 ft by 106 ft). The existing channel conditions required usage of more rudder in several of the turns than the plan condition. Plots for Reaches B, D, and E (Plates 25-27) all show reduced speed for the plan channel but also smaller peak values of rudder usage. Runs made with the Mill Cove currents (Plates 28 and 29) show that speed with the Mill Cove plan is slightly reduced over the plan condition without the Mill Cove currents, even though both conditions had similar engine usage. The rudder usage plots for the Trout River area with the Mill Cove plan (Plate 29) shows a reduction of starboard rudder required to make the Chaseville Turn versus the plan condition without Mill Cove.

Outbound, flood tide. The runs from downtown to the jetties (Plate 30) show that the pilots used similar amounts of engine rpm for both the plan and existing channels, but the speed for the proposed channel is slightly less, likely due to the larger vessel used for the proposed channel. Rudder usage appears slightly less in the turns with the proposed channel than with the existing channel. For Reaches B, C, D, and E (Plates 31-34), engine usage for both conditions is about the same and speed is still slightly less for the plan condition versus the existing condition. Usage of rudder still appears to be slightly less for the Plan C channel condition. For the Mill Cove plan (Plates 35 and 36), the pilots again tended to use less engine power and thereby reduced the speed versus the plan channel without the Mill Cove currents. Rudder usage again shows slightly smaller peak values, especially for the Chaseville Turn.

Clearance Distances

Inbound, ebb tide. The plot for the run from the jetties to downtown (Plate 37) shows similar clearances for both the existing and plan conditions; however, there are two areas that show large differences. One area of difference is the St. Johns Bluff Reach which was realigned for the plan condition and now has smaller port clearances and a turning basin (near buoy 75). The changes in this area explain the large difference in port clearance between the plan and the existing conditions. The plots for Reaches B, D, and E (Plates 38-40) show similar clearances with the plan versus the existing condition. The plan channel for Reach D (Plate 39) shows that at least one pilot went out along the northern edge of the White Shells Reach, and the inbound pilots for Reach E (Plate 40) tended to go slightly outside the defined navigation channel as they met and passed the outbound vessel for both the existing and plan conditions. The plots with the Mill Cove currents show similar clearances with and without the Mill Cove currents at Dames Point (Plate 41) and a somewhat more erratic clearance with the Mill Cove currents than without the currents at Trout River (Plate 42). This is likely due to the fact that the pilots were "feeling for" the current and allowed the vessel to wander somewhat more with the Mill Cove currents than with the Plan C channel currents without Mill Cove.

Inbound, flood tide. The plot for the run from the jetties to downtown (Plate 43) shows similar clearances for both the existing and plan conditions for the port side. The starboard side shows that the pilots tended to go well outside the northern channel limits coming out of Short Cut Turn going into White Shell Reach with the proposed channel. Other than this point, they maintained as good or better starboard clearance with the proposed channel as with the existing channel. The plots for Reaches B, C, D, and E (Plates 44-47) show similar clearances for both existing and plan channels. In Reach D (Plate 46), the proposed channel showed a tendency for the pilots to go slightly out of the channel to the north in Short Cut Turn, similar to the inbound, ebb tide condition, but not to as great a degree. The proposed channel had slightly better starboard clearance than the existing channel for Reach E (Plate 47) as the inbound vessel met and passed the outbound vessel. The plots with the Mill Cove currents show similar clearances with and without the currents in Dames Point-Fulton Cutoff (Plate 48) and slightly better starboard clearance with the Mill Cove currents in Trout River (Plate 49).

Outbound, ebb tide. The plot for the run from downtown to the jetties (Plate 50) shows similar clearances for both the existing and plan conditions, except for the areas at the St. Johns Bluff and at the proposed turning basin which were discussed in the inbound, ebb tide section. The plots for Reaches B, D, and E (Plates 51-53) show similar clearances for both conditions. The plots for the Mill Cove currents at Dames Point (Plate 54) show that the pilots averaged a smaller starboard clearance with the Mill Cove plan than without the plan. This may have been deliberate in that the pilots may have intentionally stayed nearer to the starboard edge of the channel to "feel" for the effects of the Mill Cove plan on the currents. The plots for the Trout River Reach (Plate 55) again show a more erratic clearance for the condition with Mill Cove currents. This again is due to the pilots "feeling" the current and allowing the vessels to drift with the current more than with the Plan C channel currents without the Mill Cove plan.

Outbound, flood tide. The plot for the run from downtown to the jetties (Plate 56) shows similar clearances for both the existing and plan conditions. For Reaches B, C, and E (Plates 57, 58, and 60), the clearances are similar for both conditions. For Reach D (Plate 59), the starboard clearance for the proposed channel is somewhat less than with the existing channel. The pilots tended to still go deep into the bend in the St. Johns Bluff Reach even though the channel was realigned to move away from the bluff. The plots for the Mill Cove currents at Dames Point (Plate 61) show similar clearances for both conditions. For the Trout River Reach (Plate 62), the pilots tended to stay near the starboard side, again possibly trying to "feel" the effect of the current changes made by the Mill Cove plan.

Ship Track Plots

A complete set of track plots for all the channel conditions is presented in Plates 63-202. For meeting and passing situations, an inset showing where the two vessels came closest to each other along with the clearance distances between the two vessels and the minimum distance of each vessel to the channel limits is provided. For all runs performed by the bar pilots, the inbound vessel is always a tanker, and the outbound vessels is always a container ship. For the existing condition, ebb tide, the inbound tanker is set to draft 32 ft (the maximum draft that the pilots will bring a ship in with ebb tide) and with flood tide the draft is set at 36 ft. The outbound ship for the existing conditions is always set at 36 ft. For the proposed conditions, ebb tide, the inbound tanker draft is set at 36 ft, and with the flood tide the draft is 40 ft while the outbound vessel is always set at 40 ft. The ebb tide draft for the proposed channel conditions was set at 36 ft to determine if the proposed modifications to the channel might lessen some draft restrictions placed on inbound traffic.

In runs performed by the docking pilots for the Blount Island-Dames Point turn, the vessels were always tankers drafting 30 ft. For the turning basin the vessels were always container ships with the existing condition drafting 36 ft and the proposed condition drafting 40 ft.

Entrance channel to Matthews Bridge

Inbound, ebb tide. Most pilots tended to go near the left descending channel edge at both turns at the ends of the Drummond Creek Range for both the existing (Plates 63-66) and plan conditions (Plates 67-70). The tracks for both the existing and plan conditions appear very similar.

Outbound, ebb tide. Most pilots tended to go near the right descending channel limit in the Mile Point/Sherman Cut Range but no more so with the plan condition (Plates 75-78) than with the existing condition (Plates 71-74). Runs for both existing and plan were performed very similarly.

Inbound, flood tide. The runs for both existing (Plates 79-82) and plan (Plates 83-86) conditions were performed similarly. Pilot A (plan condition, Plate 83) went well outside the channel approaching White Shells/St. Johns Bluff. The pilot may have been unsure of the new channel alignment in these reaches or distracted. For whatever reason, he turned late coming into the White Shells Reach, going well outside the defined channel. He recovered as he passed through the St. Johns Bluff Reach and completed the remainder of this run successfully. The other pilots runs give no indications of what might have happened with Pilot A.

Outbound, flood tide. All runs for both existing conditions (Plates 87-90) and plan conditions (Plates 91-94) were performed in similar fashion with no indications of any difficulties.

St. Johns Bar Cut, meeting and passing

Ebb tide. Meeting and passing was performed in similar fashion with both the existing condition (Plates 95-98) and plan conditions (Plates 99-102). Pilot B, outbound, existing channel (Plate 95), went slightly outside the defined channel near the entrance to Mayport Harbor, an area where there is depth outside the defined channel limits.

Flood tide. Meeting and passing was essentially unchanged from the existing channel (Plates 103-106) to the proposed channel (Plates 107-110). Pilot B, inbound, existing and plan conditions (Plates 104 and 108), went outside the channel limits near the Pilot Town Cut range markers. This appears as a deliberate maneuver to take advantage of depth the pilot knows exists outside the channel limits.

Training Wall Reach, meeting and passing

Meeting and passing in the Training Wall Reach is not presently being performed during ebb tide conditions due to strong crosscurrents from the Intercoastal Waterway. The proposed channel modifications will not affect these crosscurrents; therefore, all meeting and passing performed in this reach will only be done with the flood tide conditions.

Existing channel. Pilot A (inbound, Plate 111) was too close to the middle of the channel, forcing Pilot B (outbound) to go well outside the channel limits. Both Pilot B (inbound) and Pilot A (outbound, Plate 112) were out of position, meeting and passing starboard to starboard, forcing Pilot A well outside the channel limits. Pilot C (outbound, Plate 114) went slightly out of the channel during meeting and passing.

Plan channel. All runs were performed without any incidences of leaving the channel. All meetings and passings were performed with no apparent difficulty (Plates 115-118). The plan channel appears clearly superior to the existing channel for this reach.

White Shells/St. Johns Bluff, meeting and passing

Ebb tide. Inbound pilots for both existing (Plates 119-122) and plan (Plates 123-126) channels tended to go slightly out along the northern edge of the White Shells Reach, but no more so with the plan than the existing channel. Outbound runs with the plan condition still show a tendency for the pilots to go near to or slightly outside the southern channel limit in the Bluff Reach. This may be due to unfamiliarity with the new channel alignment or in a conscious effort to use the depth that the pilots believe will still be available in that bendway even after the channel realignment. All meetings and passings were performed equally as well with the plan channel as the existing channel.

Flood tide. Pilot B (inbound, existing, Plate 128) turned late or stopped turning too early coming out of Short Cut Reach into White Shells Reach, going well out along the northern channel limits of St. Johns Bluff Reach. The other inbound runs and all the outbound runs were completed without incident. For the plan conditions, Pilots A and B (Plates 131 and 132) both went outside the channel limits along the north edge of the White Shells Reach. The other two inbound runs were completed well inside the channel limits. The outbound runs all tended to go near or slightly outside the southern channel limits along St. Johns Bluff Reach. The pilots commented that this portion of the channel is naturally deep and they assumed that it would remain so, even if there was no maintenance. The alignment of the White Shells Reach for the plan condition is basically the same as that of the existing condition. It is not clearly discernable why Pilots A and B went outside the plan channel, especially Pilot A who made the same run with the existing channel condition without any difficulty.

Dames Point-Fulton Cutoff, meeting and passing

Ebb tide (Plates 135-142). Pilot B (inbound, existing and plan conditions, Plates 136 and 140) went well outside the defined channel along the northern edge of the channel adjacent to the JPA Blount Island Terminal, an area of adequate depth well outside the authorized channel. Pilot D (outbound, plan channel, Plate 141) went slightly outside the defined channel along the southern channel limit. Pilot A, inbound, and Pilot B, outbound, had fairly close meetings (less than 100 ft between the vessels) for both the existing and plan channel designs (Plates 135 and 139). Meetings and passings were generally similar for both the existing and plan channels.

Flood tide (Plates 143-150). The pilots going inbound with the existing channel conditions (Plates 143-146) tended to stay near or slightly outside the defined channel along the northern channel limits adjacent to the JPA Blount Island Terminal. Pilots B and C (outbound, existing, Plates 143 and 146) went slightly outside the channel limits along the southern channel edge opposite the JPA Blount Island Terminal. Why they did so is not readily apparent since they both had large clearances (>200 ft) between them and the other vessel. All meetings and passings were performed equally well for both the existing and plan channels.

Dames Point-Fulton Cutoff, Plan C with Mill Cove Plan 5 currents

These runs evaluating the current effects of the installation of Mill Cove Plan 5 from the TABS hydrodynamic model were added after the first two bar pilots had completed their scheduled operations; therefore, there are only two pilots who performed operations using the Mill Cove Plan.

Ebb tide. Meetings and passings were performed in a similar fashion to Plan C channel (Plates 151 and 152). Again the pilots tended to go near or outside the southern channel limit near the opening to Mill Cove. Pilot C went well outside the channel limit (Plate 152), even though he had a distance between vessels of over 300 ft when passing. Why he went out so far is not apparent.

Flood tide. The meeting and passing with the Mill Cove Plan currents is similar to those without the Mill Cove currents (Plates 153 and 154). The pilots tended to stay within the defined channel better with the Mill Cove currents than without. This caused a reduction of the clearance distance between the two vessels (169 ft with the Mill Cove Plan 5, down from 239 ft without the Mill Cove Plan) but still provided adequate clearance to safely meet and pass.

Training Wall Reach, Plan C with Mill Cove Plan 5 currents

Ebb tide. The inbound runs are similar to the existing conditions and Plan C (Plates 155 and 156). The vessel still tends to set toward the right descending bank near the southwest end of Noname Island. The set does not appear either better or worse than the existing or Plan C conditions. The first runs, by the outbound pilots were "experiments" (Plates 157 and 159). For these runs, the pilots let the vessel mostly drift through the Chaseville Turn to determine if the set that is normally experienced in this area during ebb tide was diminished. Pilot C was able to complete the turn without leaving the channel but Pilot D went well outside the left descending bank channel limit. During the second run both pilots more actively piloted the vessel, completing the turn with little difficulty (Plates 158 and 160).

Flood tide. The inbound runs (Plates 161 and 162) were made without difficulty, in a manner similar to that of the existing condition and Plan C. The outbound runs were also performed without difficulty (Plates 163 and 164). The Mill Cove Plan 5 appears to have not appreciably changed the current effects that the pilots normally experience in this area.

Blount Island Channel/Dames Point-Fulton Cutoff Channels

Ebb tide. The inbound runs for the existing condition show that Pilot E (Plate 165) made a fully successful turn, and Pilot F (Plate 166) went slightly outside Blount Island Channel on the west side. The runs for the Plan C condition show that Pilot E (Plate 167) turned a little too early before the ebb current could push the vessel eastward sufficiently and went slightly outside the west side of the Blount Island Channel. Pilot F (Plate 168) turned too early and went outside the channel on the southwest corner of the Dames Point-Fulton Cutoff/Blount Island Channel intersection. For the outbound runs with the existing channel (Plates 169 and 170), both pilots allowed the bow of their vessels to begin turning too early and therefore let the bow swing out across the southwest corner of the channel intersections. For the Plan C channel condition (Plates 171 and 172), the pilots did almost exactly the same thing, but not to any greater extent than in the existing channel.

Flood tide. For the inbound runs, Pilot E made two attempts to enter the Blount Island Channel (Plates 173 and 174). On the first attempt he went too far west with the current and turned late. In the second attempt, he turned much earlier and clipped the southwest corner of the channel intersection. Pilot F (Plate 175) turned similar to the manner of Pilot E on his second attempt, turning early, clipping the southwest corner of the channel intersection, and then backed off the turn too early, allowing the vessel to slide outside the western channel limit of the Blount Island Channel. For the Plan C channel (Plates 176 and 177), both pilots turned early near the intersection of the channels with Pilot E going well outside the channel limits and Pilot F remaining inside the channel. Then both pilots drifted across the Blount Island Channel and went outside the defined channel along the western edge. For the existing condition, outbound (Plates 178 and 179), both pilots tended to start their turns early and clipped the southwest corner of the channel intersection, with Pilot E going well outside the channel limits. With the Plan C channel condition (Plates 180 and 181), the pilots backed out of the Blount Island Channel further before turning the bow. Pilot E went only slightly outside the channel at the southwest corner intersection, and Pilot F went slightly outside the northern edge of the Dames Point Channel near the Dames Point Bridge with his stern.

Long Branch/Terminal Channel turning area

Ebb tide. With the existing channel, inbound (Plates 182-184), neither pilot was able to complete a turn before drifting outside the eastern edge of the Long Branch Channel. With the proposed turning basin (Plates 185-187), neither pilot was able to complete the turn before going outside the eastern edge of the Long Branch Reach. With the existing channel outbound (Plates 188 and 189), both Pilots E and F were able to complete the turns by starting their turns as the bows passed buoy 75 and by letting the bows swing well outside the 30-ft contour used for the channel's southern edge for turning maneuvers; then, they completed their turns just before entering the Long Branch Reach. For the Plan C basin design, the pilots were not allowed to begin their turns until they were completely in the basin. Neither pilot (Plates 190 and 192) was able to complete the turn. Pilot E recommended that the corner of the turning basin between buoy 75 and the southwest corner marker for the basin be dredged to allow for the turn to begin earlier, much like the existing condition. Pilot E was given the opportunity to try this by assuming that the northwest marker of the basin did not exist and the channel was dredged as he had requested (Plate 191). The pilot was able to complete the turn by using the extra room provided. He next was allowed to use this same basin design along with having up to four 3,000-hp tugs available (three tugs at the stern, one at the bow) (Plate 192). He was able to turn the vessel with relatively little difficulty. For the last trial, the pilot was asked to use the original design of the turning basin but was allowed to have four 3,000-hp tugs. With this scenario (Plate 193) he was unable to complete the turn before going outside the channel limits in the Long Branch Reach.

Flood tide. The existing condition, inbound runs were successfully made by both pilots (Plates 195 and 196), using only about half of the available area. Both pilots were able to make successful runs in Plan C (Plates 197 and 198); however, Pilot F turned farther west and his stern swung outside the defined channel along the north edge of the Terminal Channel. This movement by Pilot F was acceptable since the area he swung into would have depth outside the defined channel. In the outbound runs with the existing conditions (Plates 199 and 200), both pilots were able to complete their turns even though Pilot F started his turn farther west than Pilot E and let his stern swing outside the defined channel along the southwestern edge of the "existing turning area." For the Plan C condition (Plates 201 and 202), both pilots were able to turn their vessels successfully even though both let their sterns swing outside the defined channel along the north edge of the Terminal Channel in an area with depth outside the defined channel.

5 Conclusions and Recommendations

Limitations of the Study

There are at least two factors that should be considered when evaluating the results of the piloted runs. The first factor is the limitation of the view that was available to the pilot. The visual software available at the time of this study did not have the capability of allowing either the ability to turn the view to some direction other than directly ahead or to walk out on the wings to get a better view alongside the vessel. The pilot was restricted to the straight ahead view standing midway of the beam width. The pilots had three viewing screens with a total view of approximately 120 deg. This limited the ability of the pilots to use visual references on the sides of the vessel, making them rely more heavily on radar than would normally be the case. This limited visual information was especially critical to the docking pilots when they were performing turning maneuvers.

The second factor to be considered is the lack of depth perception of the visual images. Several pilots noted that distant channel buoys appeared almost as close as near buoys. This again forced the pilots to rely more on radar than their visual references. One pilot commented that he normally used 90 percent visual references and 10 percent radar, but with the lack of depth perception in the visual scene, he was doing almost the opposite, relying almost exclusively on the radar. This change from normal operation by the pilots may have influenced the outcome of some runs, especially those where the channel was modified and the buoys marking the channel had been moved. The combination of lack of depth perception and unfamiliarity with the new channel design/alignment may have added a factor of difficulty to runs that was not intended.

Although the previously described limitations made operation for the pilots more difficult, they will also tend to make the results of this study more conservative. Most runs by the pilots for existing and plan conditions were performed successfully. The run scenarios were set up as the "maximum creditable adverse conditions" for current, wind, and vessel size. The ability of the pilots to successfully navigate the channel in these "worst case" conditions, along with the limitations of the simulation, would tend to confirm that the channels could be navigated successfully in the prototype under more favorable conditions with acceptable levels of difficulty and safety.

Conclusions

The average ratings of the individual runs showed that Plan C tended to be rated as the same or slightly less difficult than the existing conditions. There were some scenarios, such as with Reach B, outbound, flood tide, that rated the Plan C channel as significantly more difficult. Other scenarios had Plan C rated as more difficult, but the differentials in the ratings of the existing condition to the plan condition were usually small.

The pilots tended to rate the Plan C channel with the Mill Cove Plan 5 currents as about the same as Plan C without the Mill Cove plan in the Dames Point/Fulton Cutoff Reach and more difficult in the Trout River Cut.

The final pilot questionnaire shows that three out of four bar pilots favored the Plan C channel design. These pilots said that there would be no significant changes to operations by restricting meeting and passing of two large vessels to east of the Dames Point Bridge. The pilots also said that the changes in currents by the installation of the Mill Cove Plan 5 would not affect their operations and could possibly improve the navigation conditions. The fourth pilot was not opposed to the Plan C channel design, but thought that it did not go far enough since it did not propose to widen Drummond Creek and Trout River Reaches as much as he would like. None of the pilots thought that any changes being proposed would change the draft restrictions on inbound vessels during ebb tide from what they are now.

The docking pilots stated that turning operations in the Blount Island Channel would not significantly change even if larger vessels call. Both pilots approved of the proposed turning basin. One pilot suggested an enlargement of the basin to the southwest that would make it possible to turn vessels in a strong ebb tide. The other pilot stated that they normally would not attempt to turn a large or poor handling vessel until near slack tide.

The parameter plots showed that engine and rudder usage were not significantly different for the Plan C channel versus the existing channel. Vessel speed was somewhat reduced for the plan channel, likely due to the use of the larger, deeper draft vessels. Clearance distances for the Plan C channel and the existing channel were similar. All of this indicates little difference in the ability to navigate in either channel.

The parameter plots of the Plan C channel condition with and without the Mill Cove Plan 5 installed again showed little differences. There were some indications that the Plan C channel with the Mill Cove plan might be slightly better.

The track plots of all the piloted runs with the existing conditions and the Plan C channel indicated that transits and meeting and passing can be performed at least as well with Plan C as with the existing conditions. The only area that showed significant problems with Plan C was in the White Shells/St. Johns Bluff area. This was an area of a major realignment which may have made the Plan C runs with meeting and passing appear more difficult. On all outbound transits and three out of four inbound transits (Reach A), the pilots made successful passage through this reach. The inbound run that did not successfully make the turn went well outside along the north at Short Cut Turn, similar to the way that most of the runs with the meeting and passing in the White Shells/St. Johns Bluff Reach also went. There is no apparent reason for this except for some indecision by the pilots likely due to the realignment.

The tracks for the Plan C Channel with and without the Mill Cove plan again showed little difference, except for the outbound ebb tide runs in the Trout River Reach. As described earlier, the pilots tended to let the vessel "drift" through the Chaseville Turn so they could better determine the change in current effect caused by the Mill Cove plan. When the pilots repeated these runs and more actively piloted the vessels, they were completed successfully.

Based on the pilots' individual run evaluations, the final questionnaires, parameter plots, and ship track plots, the following conclusions can be drawn:

a. The Plan C channel design appears to provide comparable degrees of difficulty and safety to the existing channel conditions for the study area and provides improvement over the existing channel conditions in the Training Wall Reach.

b. Meeting and passing situations using the Plan C channel design can be performed as well as or better than with the existing conditions.

c. The inbound tanker drafting 36 ft with the Plan C channel design and ebb tide was comparable in difficulty and safety to that of the existing channel conditions with ebb tide drafting 32 ft.

d. The Mill Cove Plan 5 modifications do not appear to significantly alter the difficulty of transits at the inlet along the Dames Point-Fulton Cutoff Reach, but based on pilot evaluations may be significantly more difficult during outbound transits with ebb tide at the outlet along the Trout River Reach as compared with the Plan C channel conditions without the Mill Cove plan.

e. Turns into and out of the Blount Island Channel will not be significantly more difficult with the Plan C channel design.

f. The proposed turning basin will provide adequate space to turn large vessels except during peak ebb tide.

Recommendations

Based on the piloted simulation results, comments made by the pilots, and conclusions reached, WES proposes the following recommendations:

a. The Plan C channel design should be adopted. At least one pilot commented that restrictions of meeting and passing of two large vessels in the reaches east of the Dames Point Bridge with the proposed Plan C are basically the same as with the present channel design.

b. Range markers for inbound traffic to Drummond Creek Range should be added as suggested by pilots.

c. Turning of large vessels in the proposed turning basin during ebb tide conditions should be restricted. A docking pilot suggested enlargement of the basin which might provide for around-the-clock capability for turning a vessel; however, a second docking pilot noted that, at present, large or poor handling vessels are turned only at or near slack tide. The enlargement of the proposed basin should only be considered if the restriction of being unable to turn a vessel during ebb tide is a serious limitation.

d. Additional consideration of the realignment of St. Johns Bluff Reach may be necessary. Several pilots commented that this reach was used by docking pilots to turn large vessels, and the bar pilots noted that they commonly meet ocean going barges on long hawsers in this reach. The reduction of width (moving the channel north away from the bluff) did not seriously impact operations with the piloted vessels, but availability of this additional width may be critical for meeting and passing the towed oceangoing barges. The loss of this area for turning vessels may also present problems unless a turning basin is provided.

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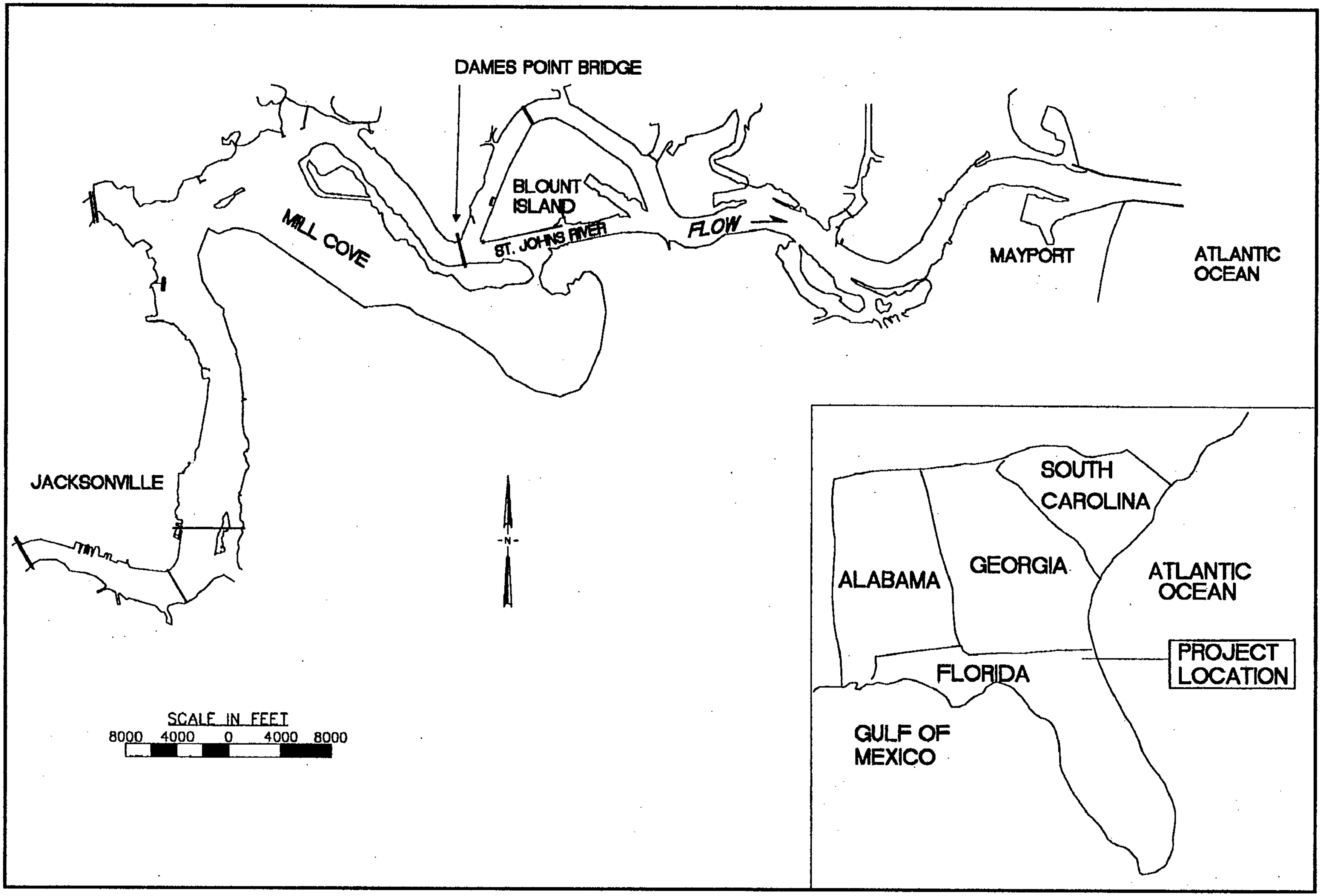

Figure 1. Location map

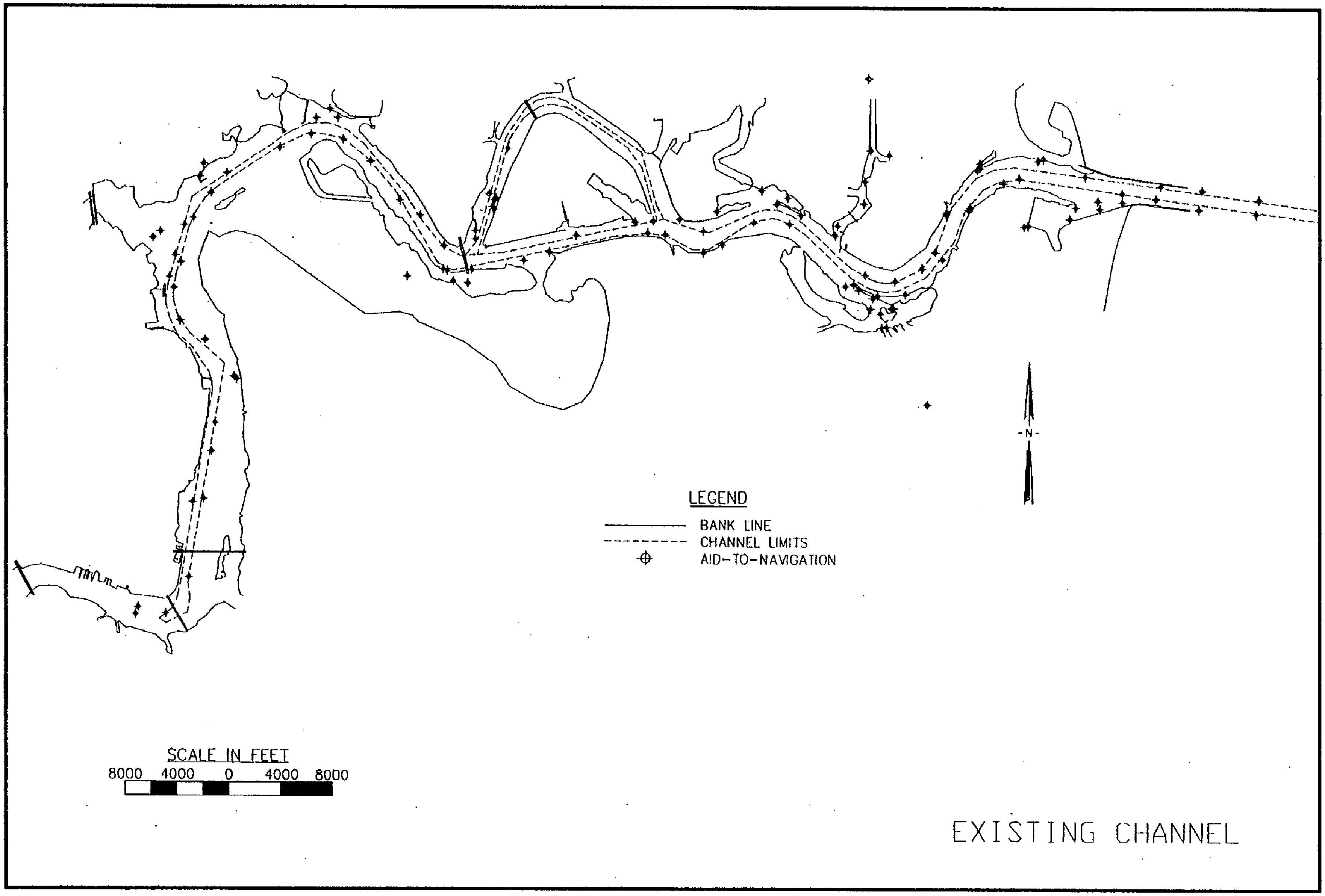

Figure 2. Existing channel conditions, 38 ft, mlw

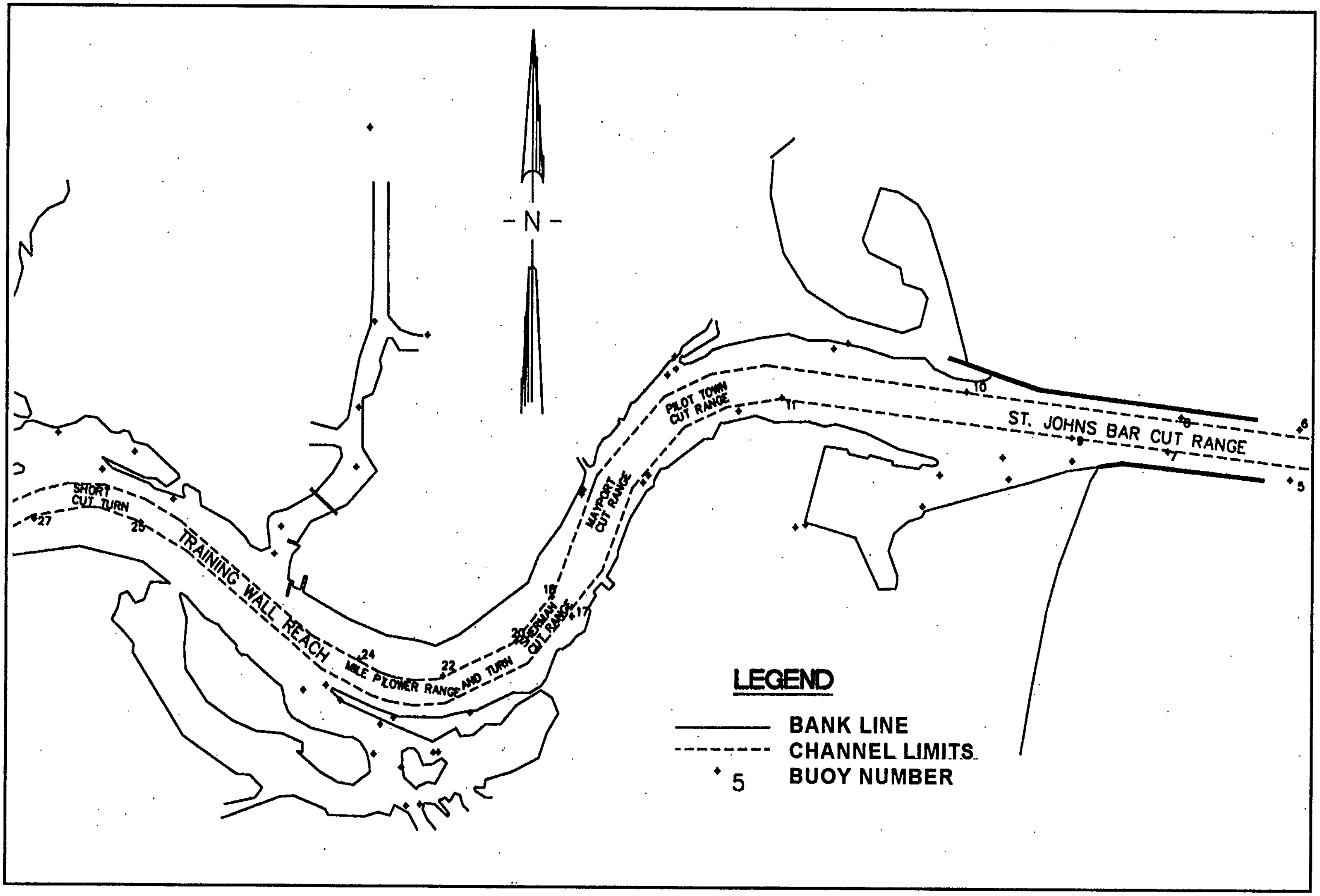

Figure 3. St. Johns River, Buoys 5 through 27

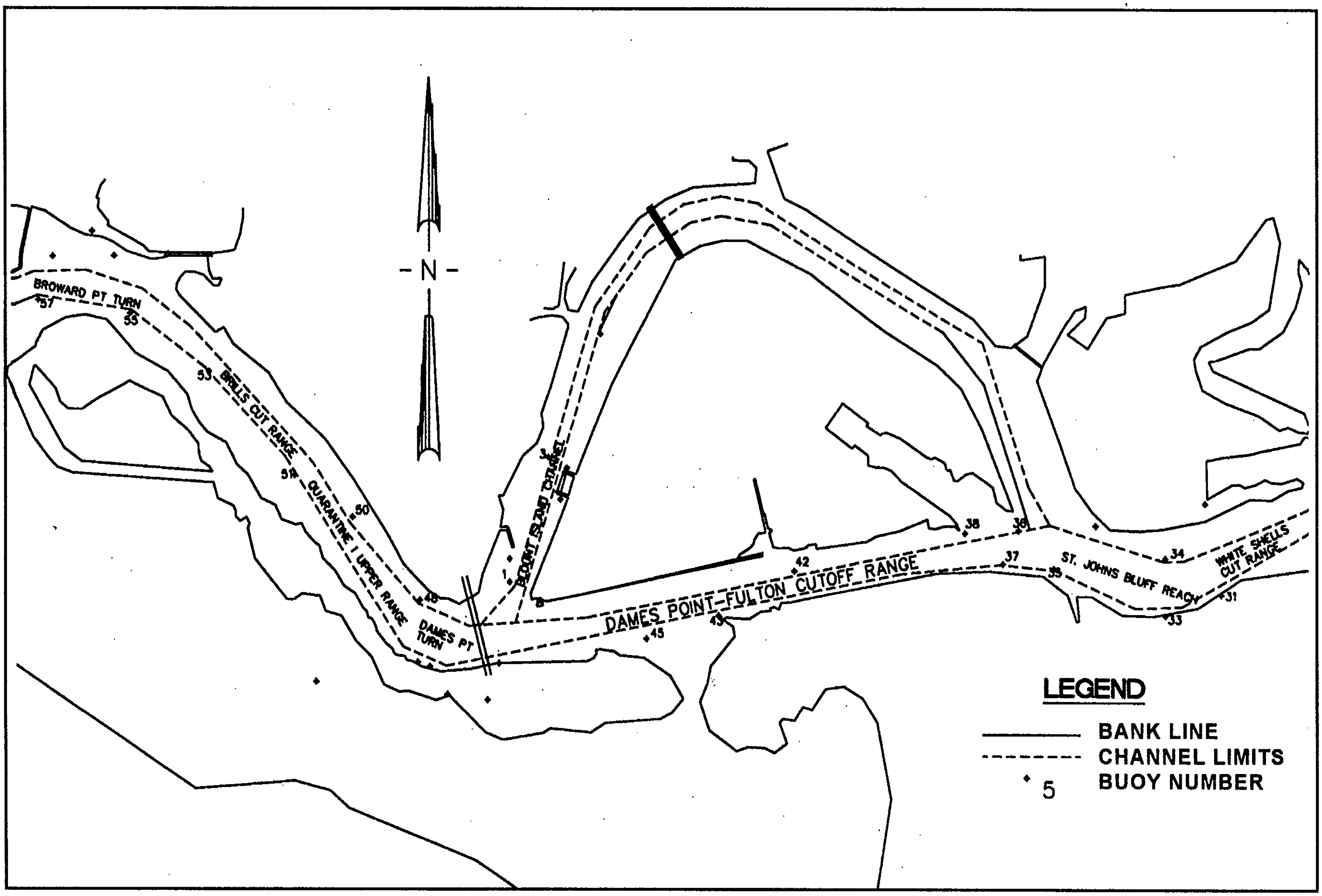

Figure 4. St. Johns River, Buoys 31 through 57

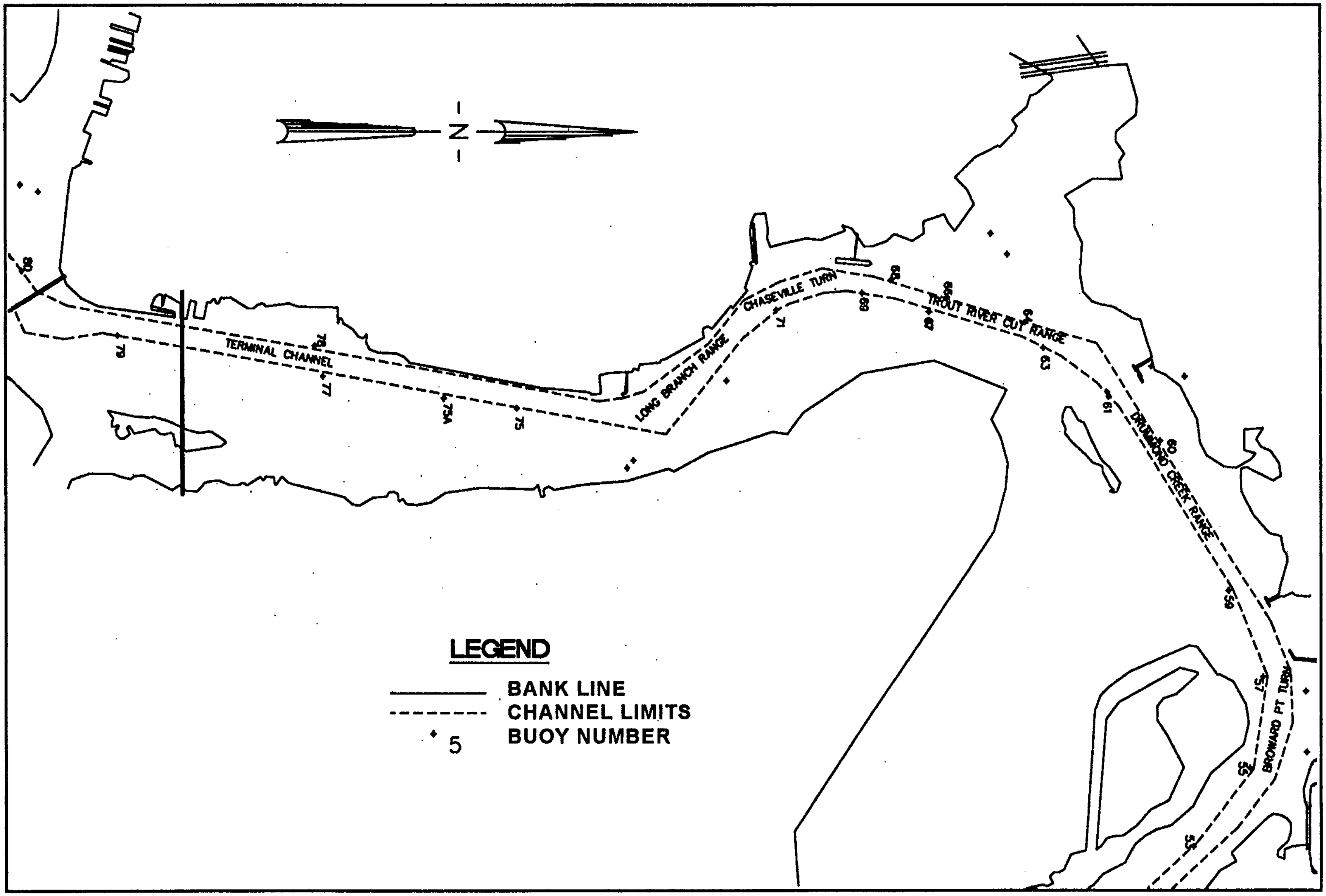

Figure 5. St. Johns River, Buoys 53 through 80

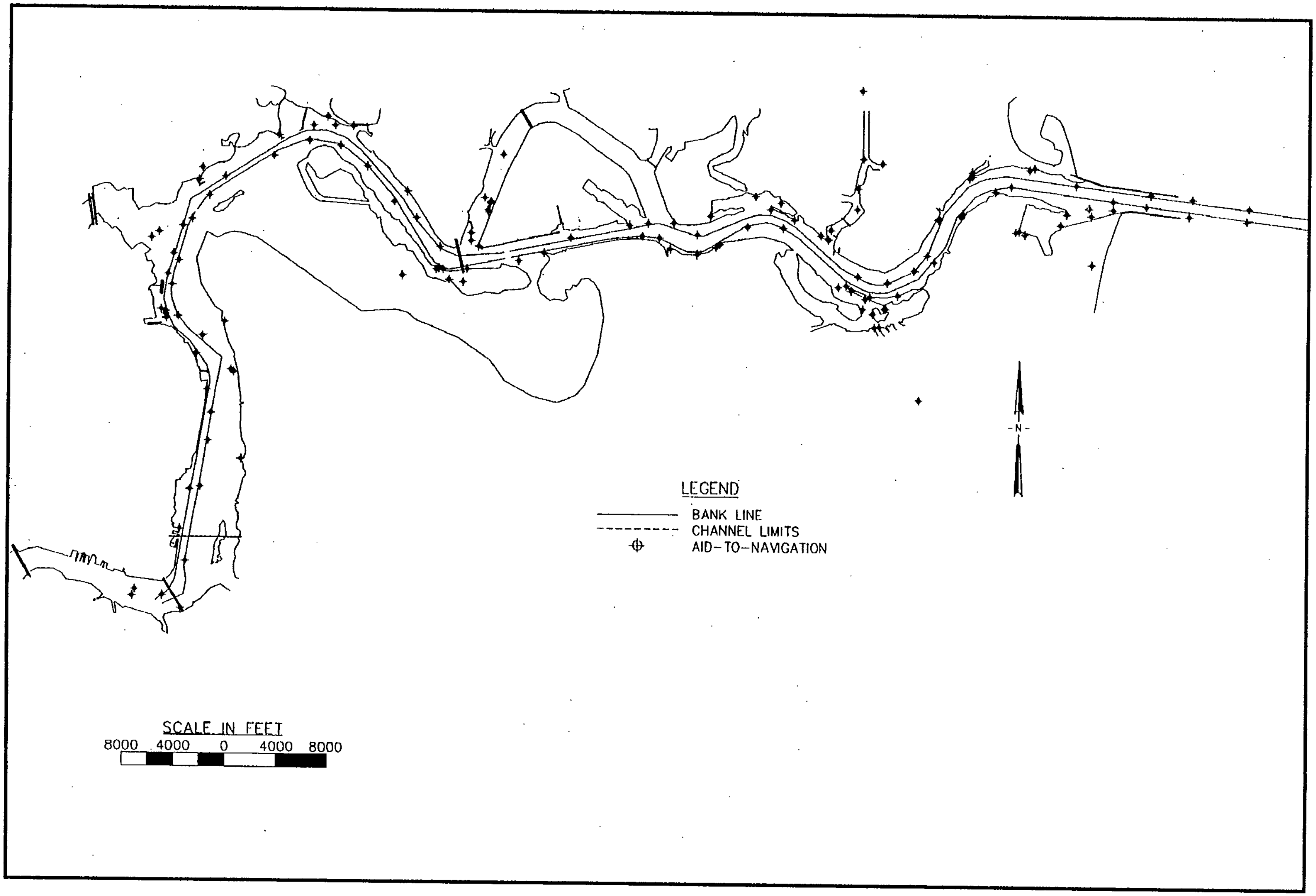

Figure 6. Plan A channel

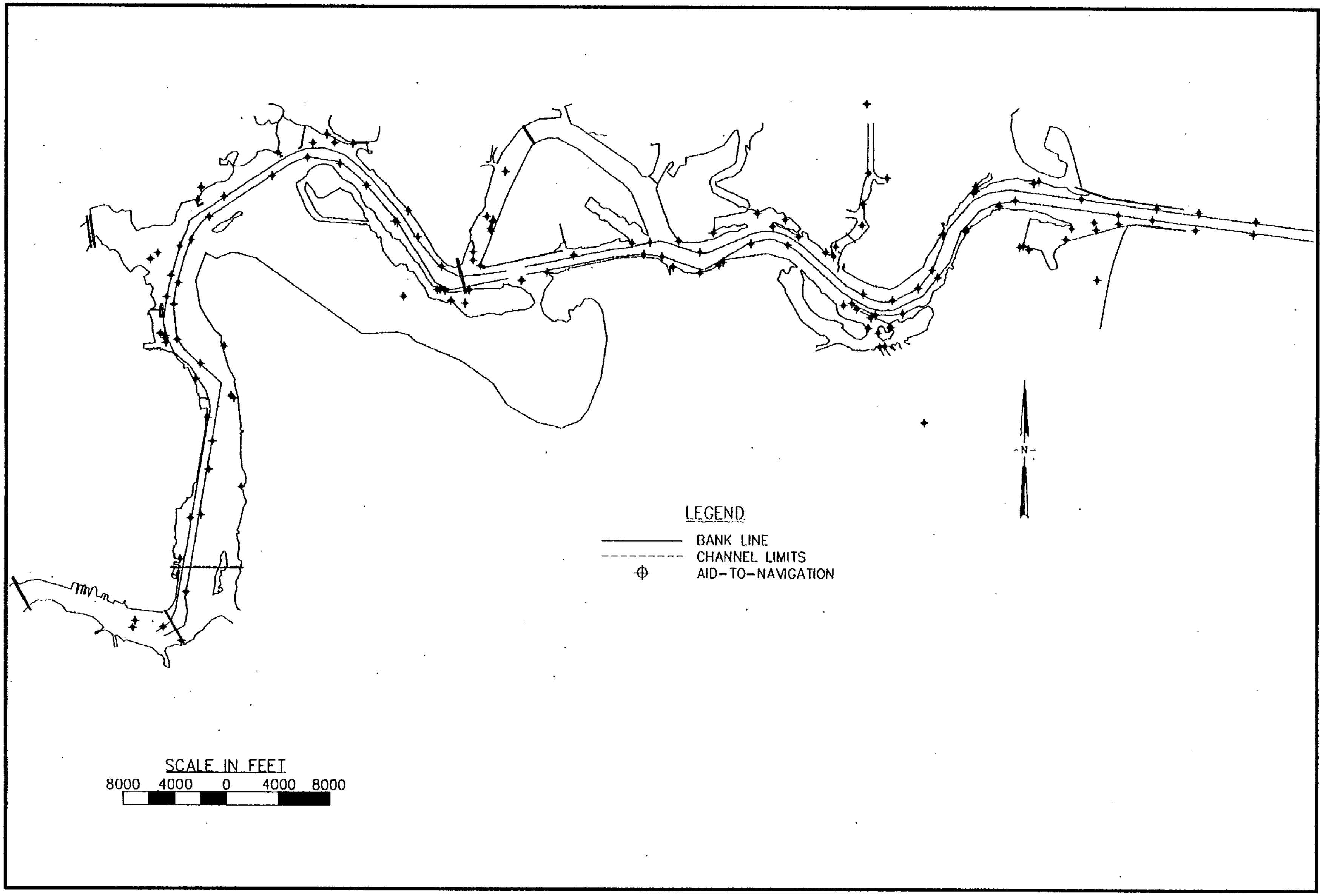

Figure 7. Plan B channel

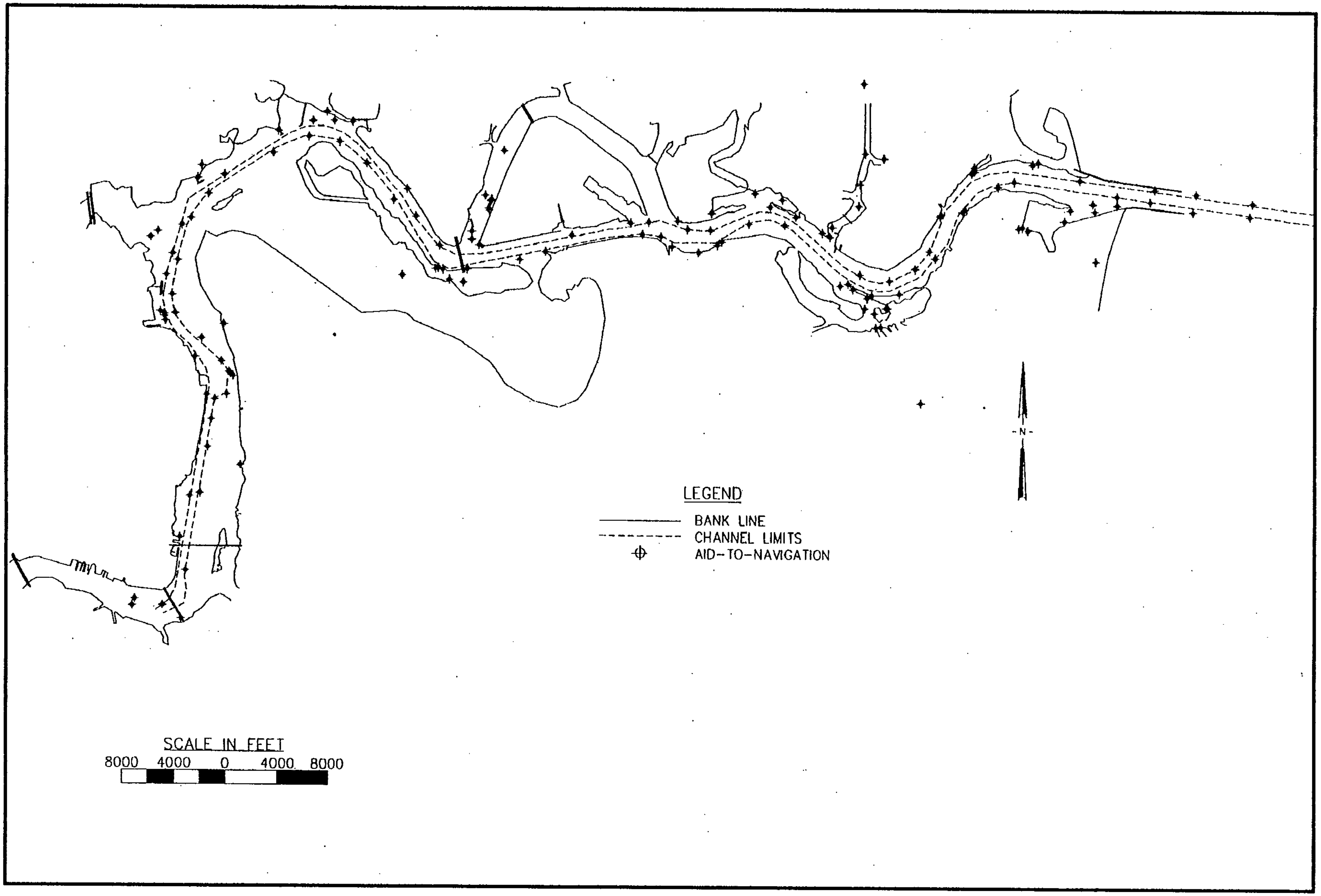

Figure 8. Plan C channel

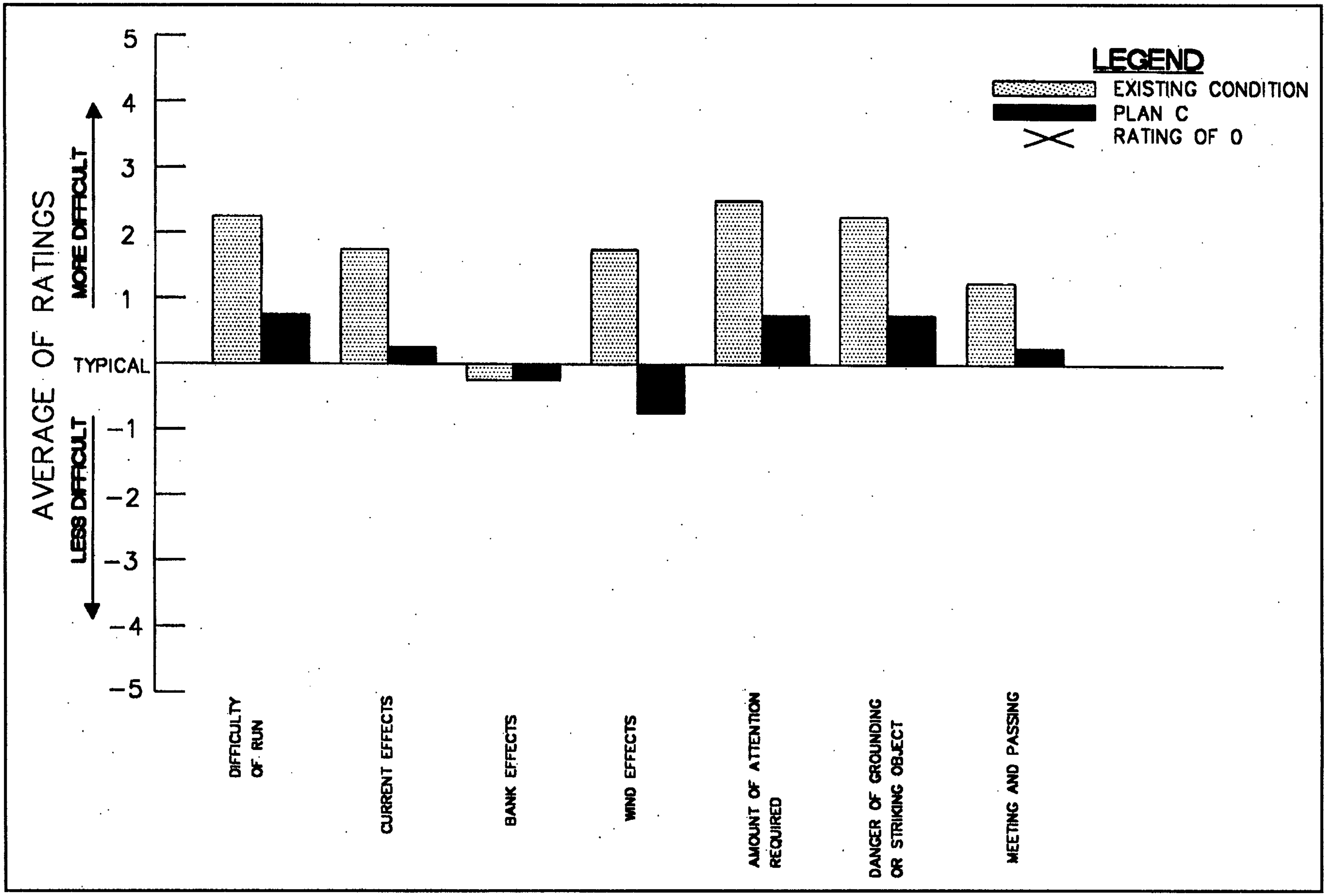

Figure 9. Pilot ratings, jetties to Matthews Bridge, inbound, ebb tide

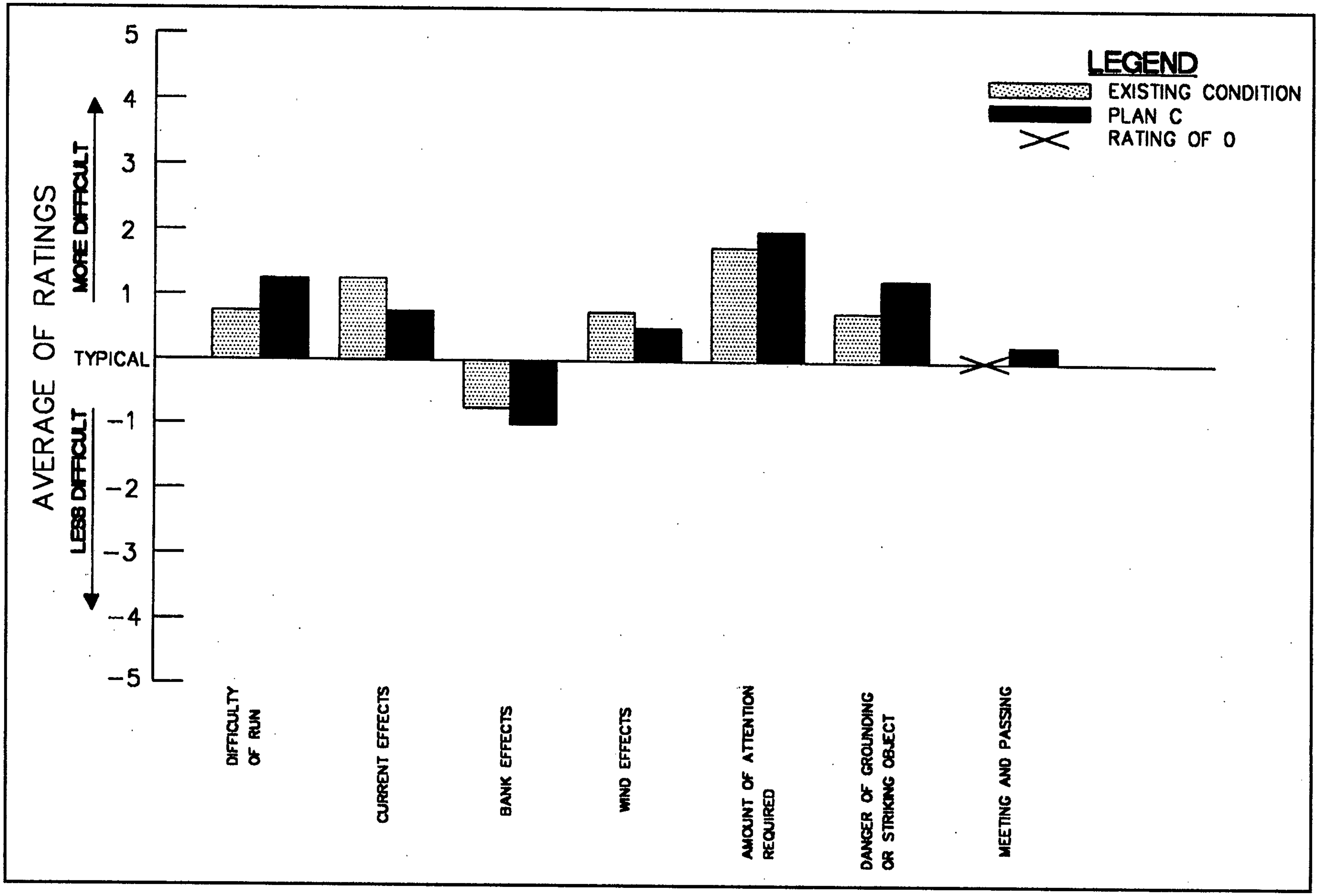

Figure 10. Pilot ratings, jetties to Matthews Bridge, outbound, ebb tide

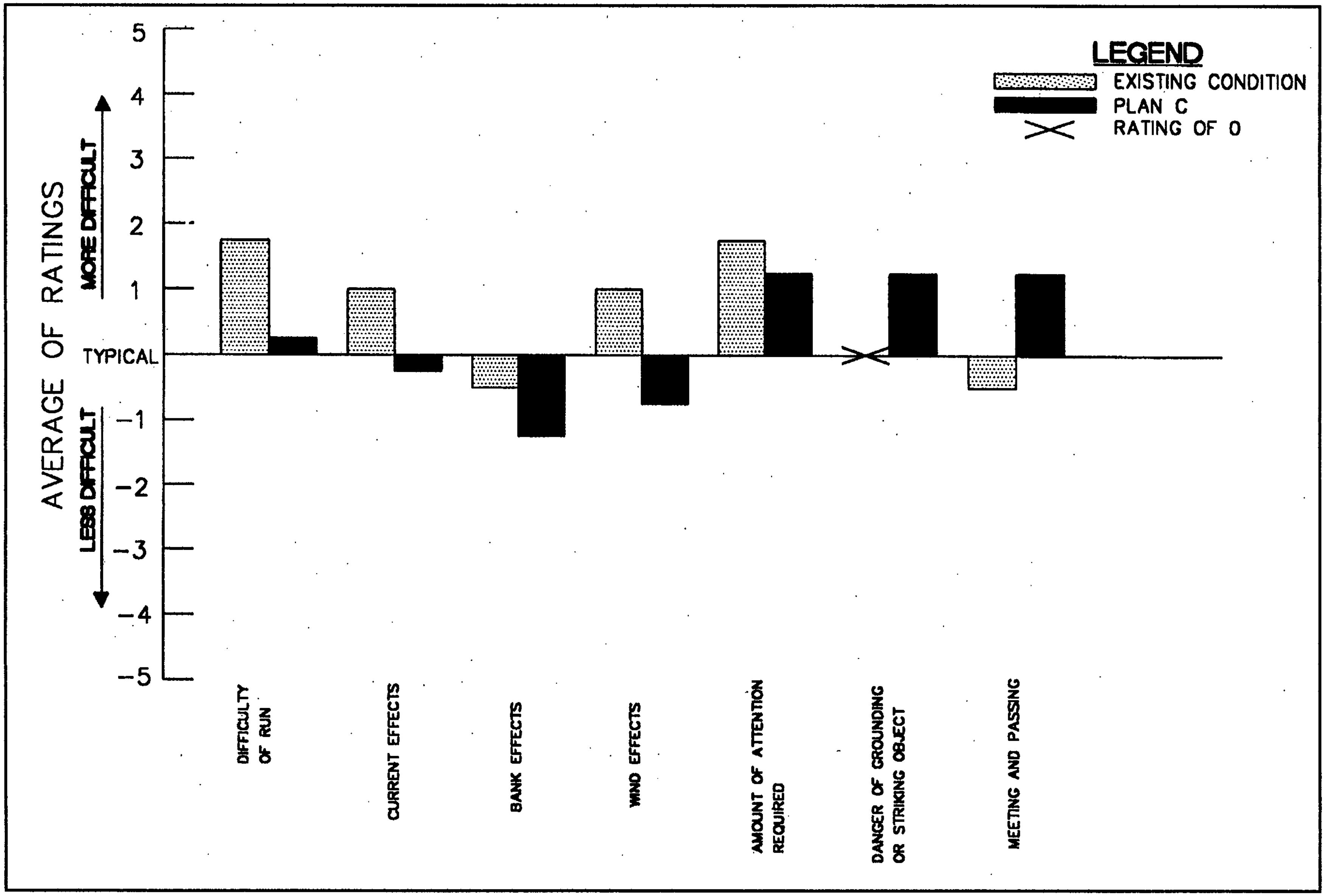

Figure 11. Pilot ratings, jetties to Matthews Bridge, inbound, flood tide

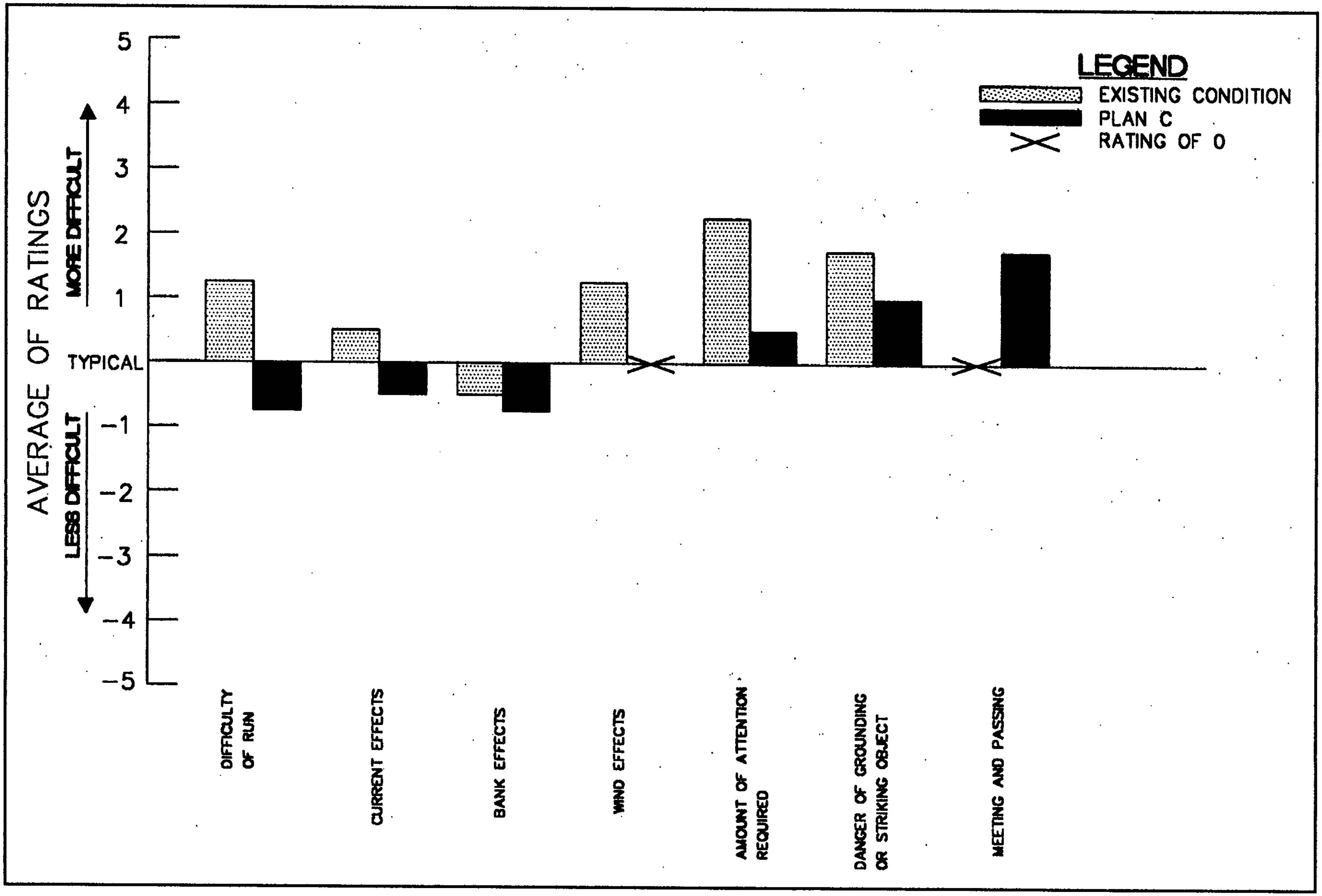

Figure 12. Pilot ratings, jetties to Matthews Bridge, outbound, flood tide

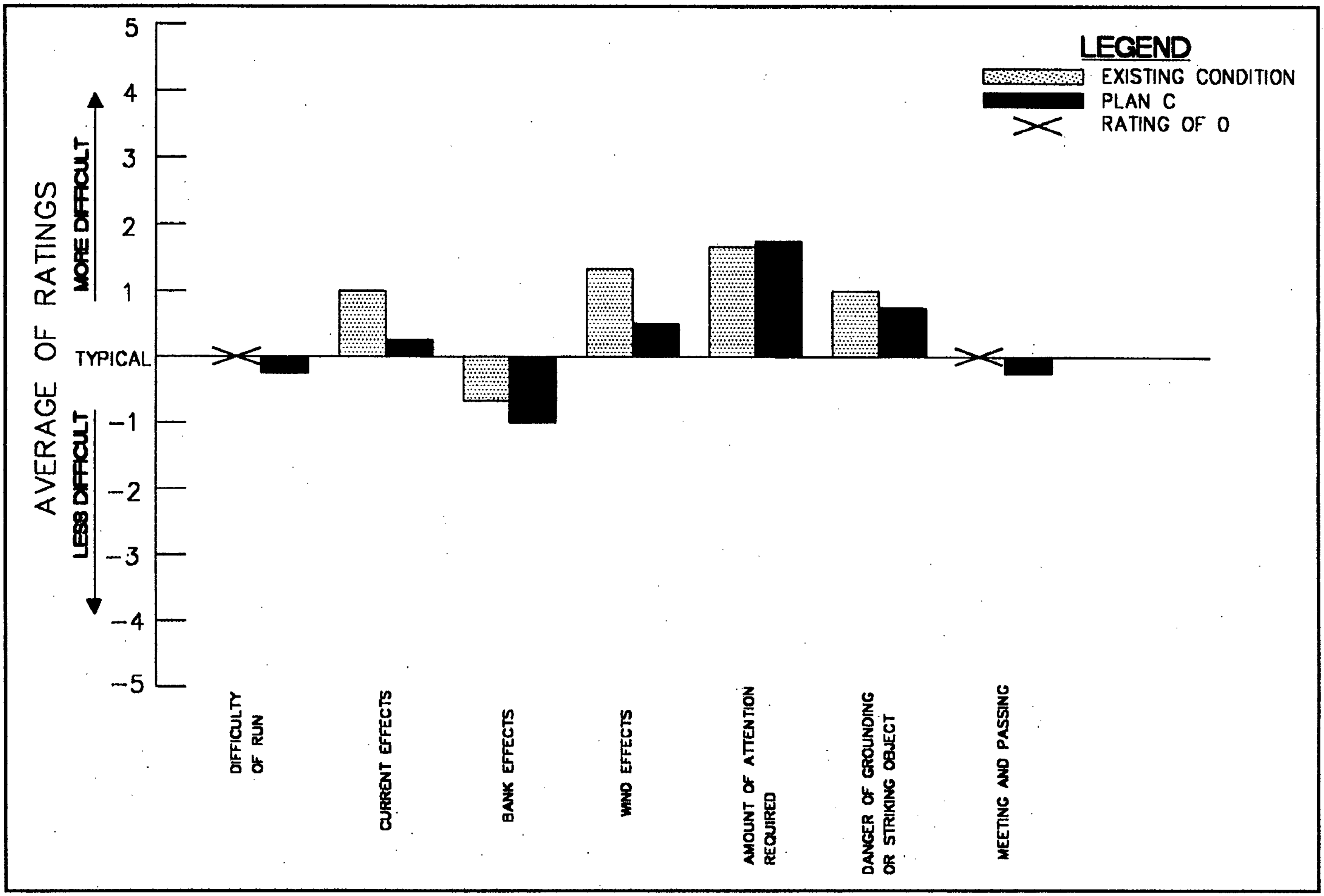

Figure 13. Pilot ratings, St. Johns Bar Cut, inbound, ebb tide

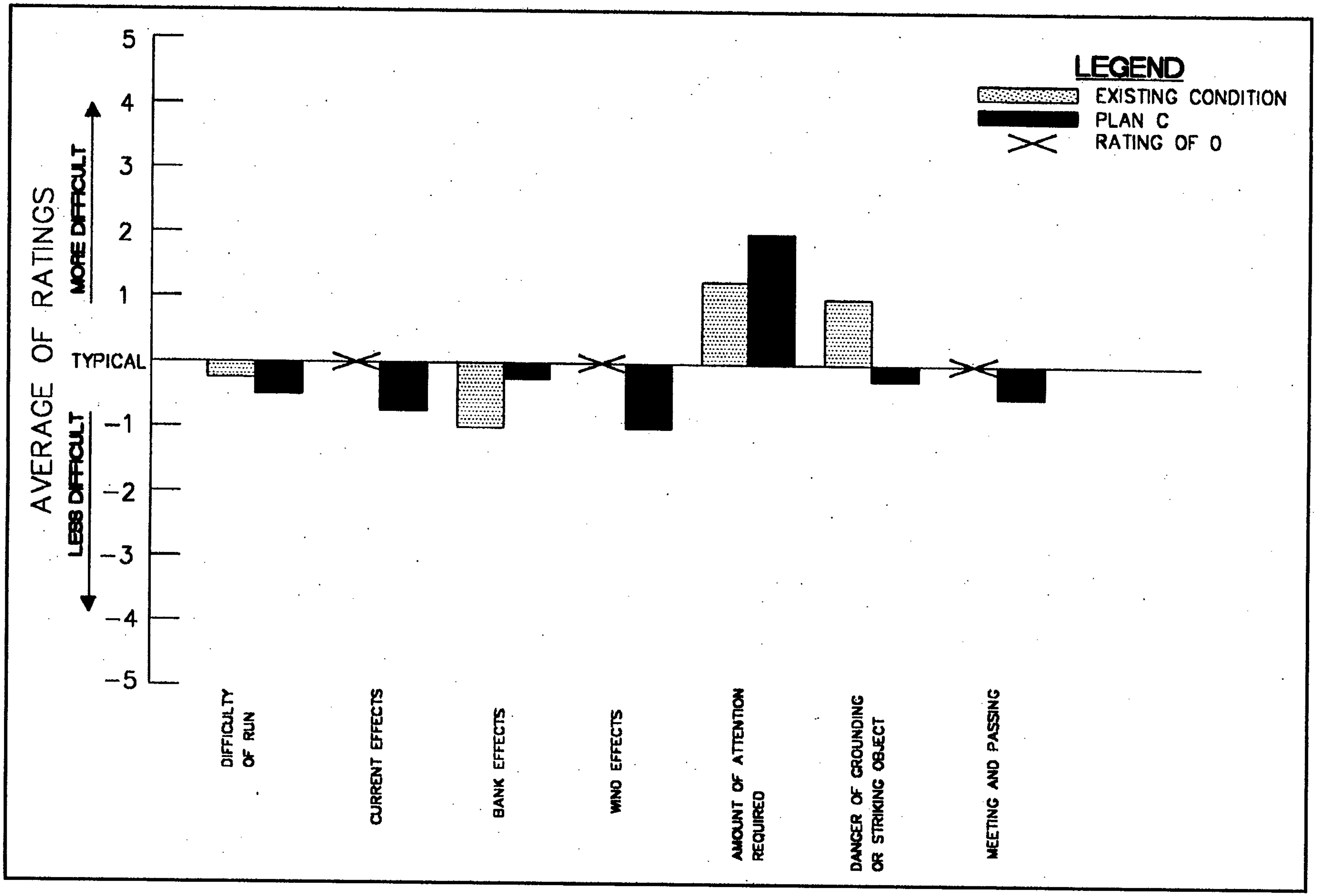

Figure 14. Pilot ratings, St. Johns Bar Cut, outbound, ebb tide

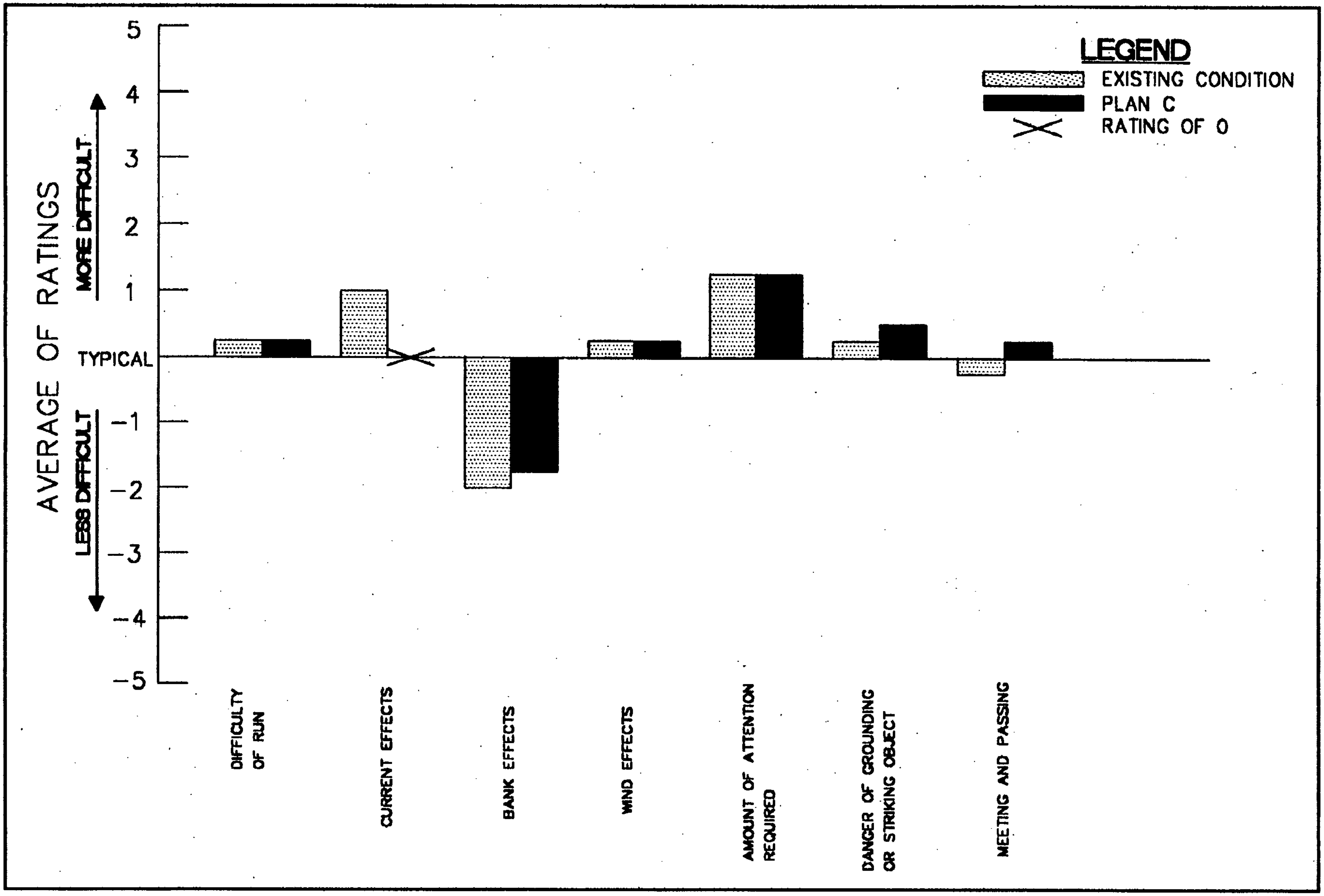

Figure 15. Pilot ratings, St. Johns Bar Cut, inbound, flood tide

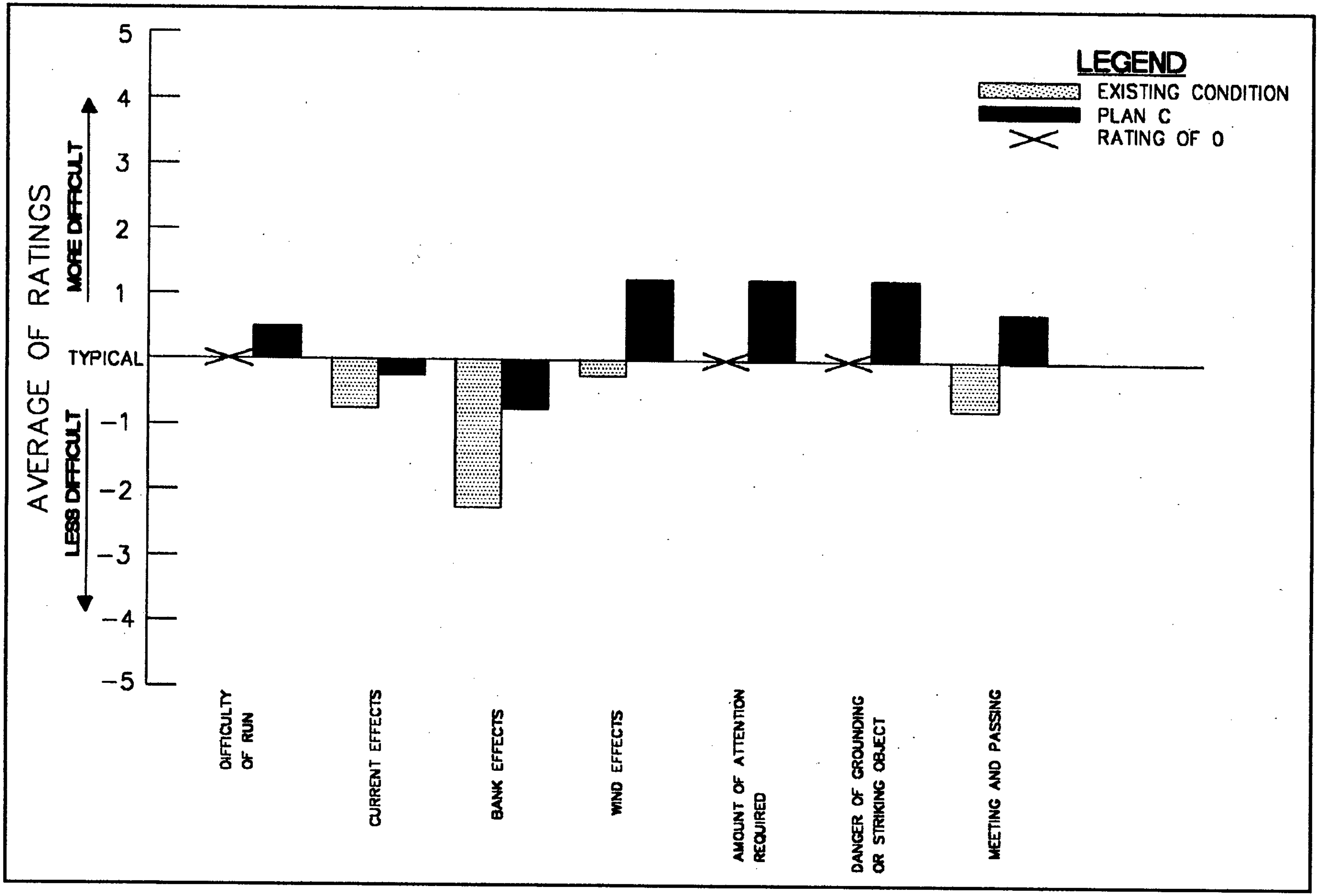

Figure 16. Pilot ratings, St. Johns Bar Cut, outbound, flood tide

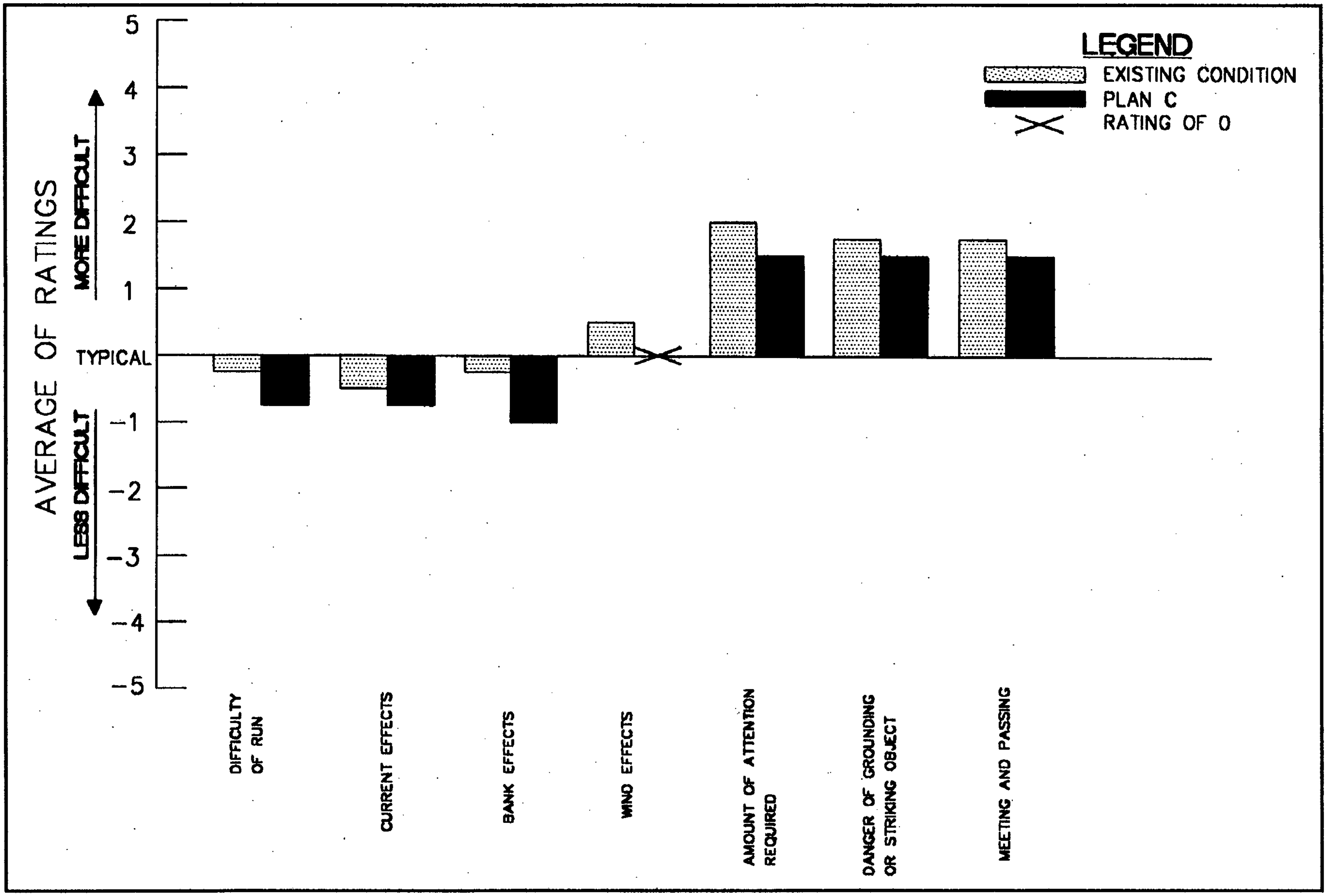

Figure 17. Pilot ratings, Training Wall, inbound, flood tide

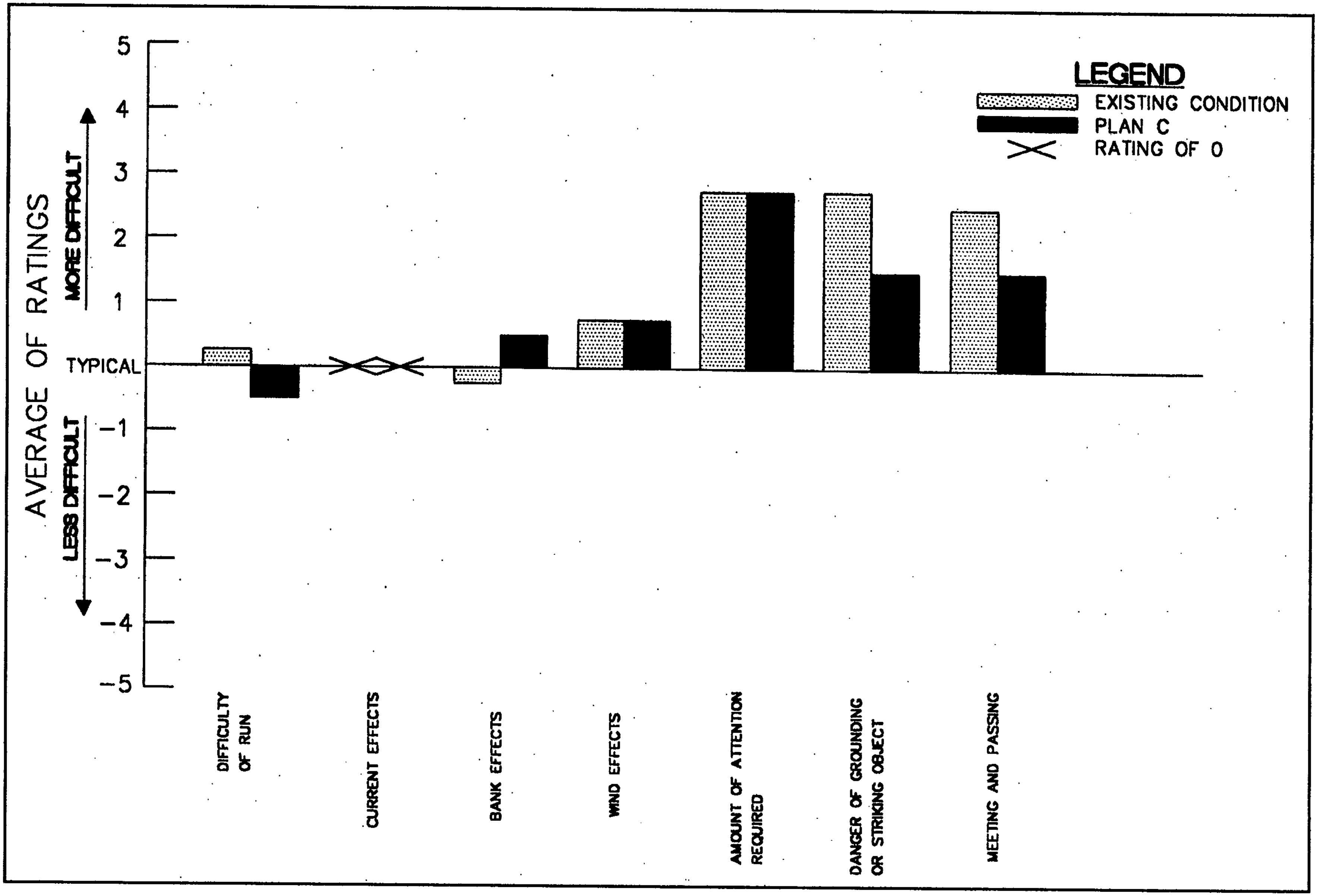

Figure 18. Pilot ratings, Training Wall, outbound, flood tide

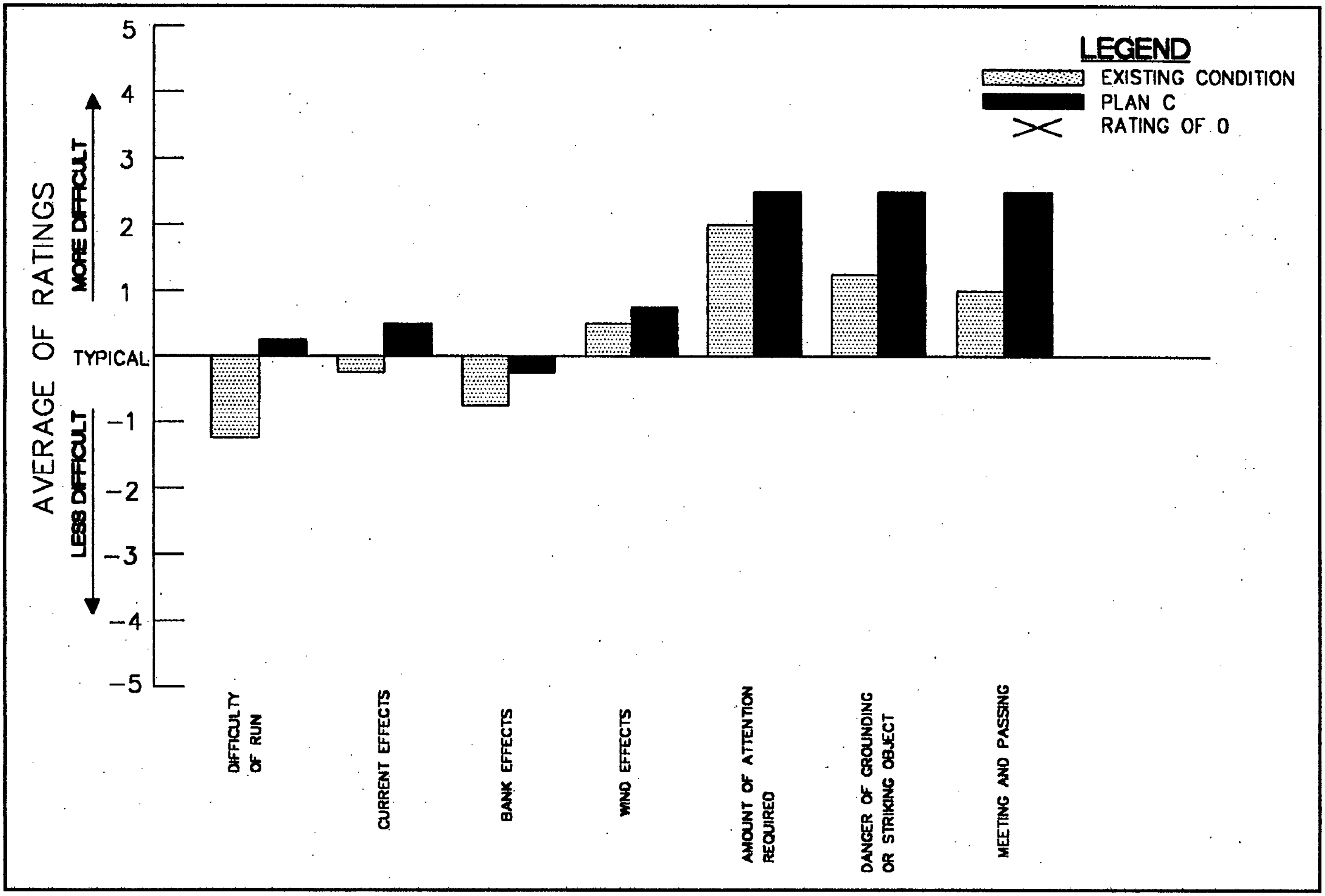

Figure 19. Pilot ratings, St. Johns Bluff, inbound, ebb tide

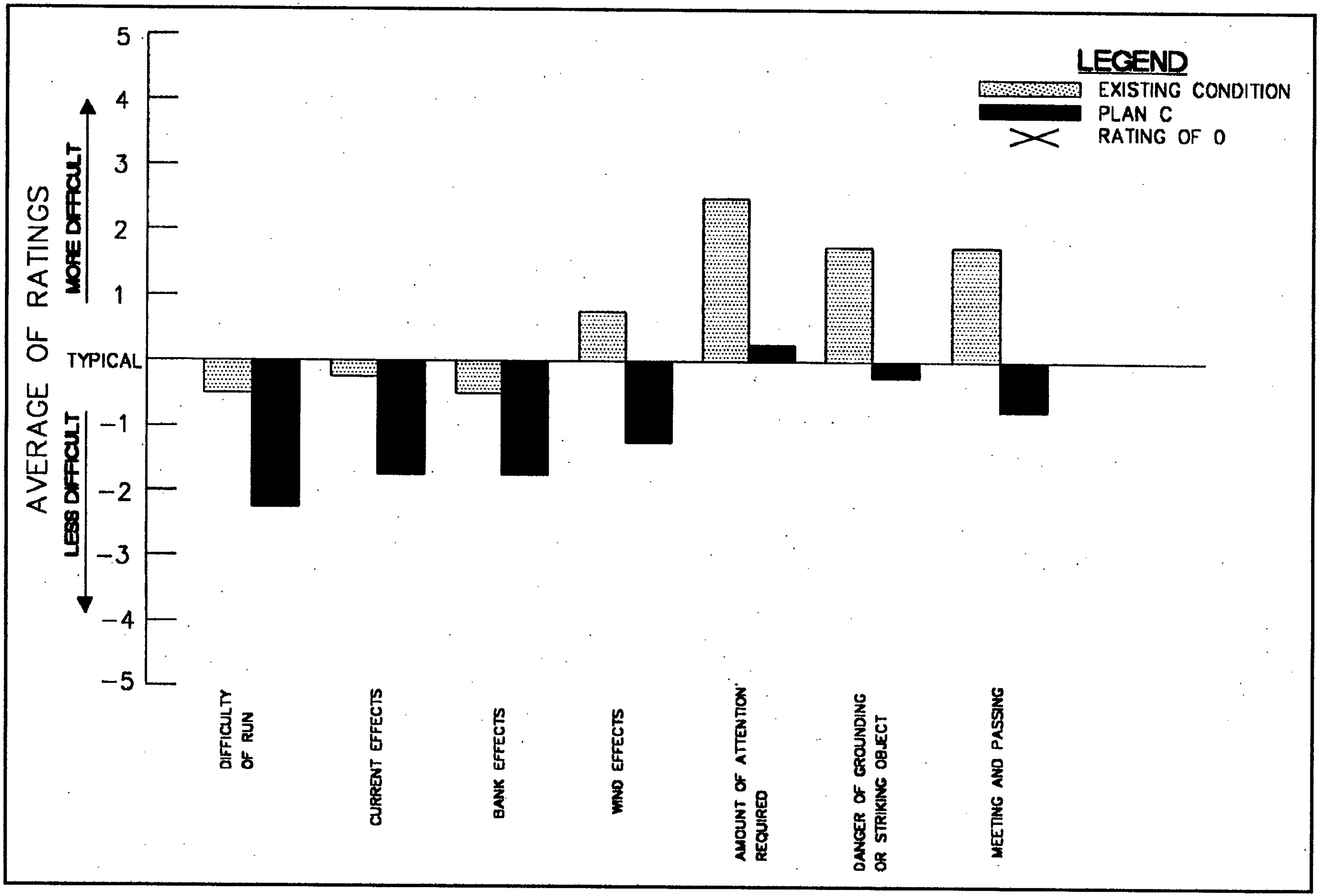

Figure 20. Pilot ratings, St. Johns Bluff, outbound, ebb tide

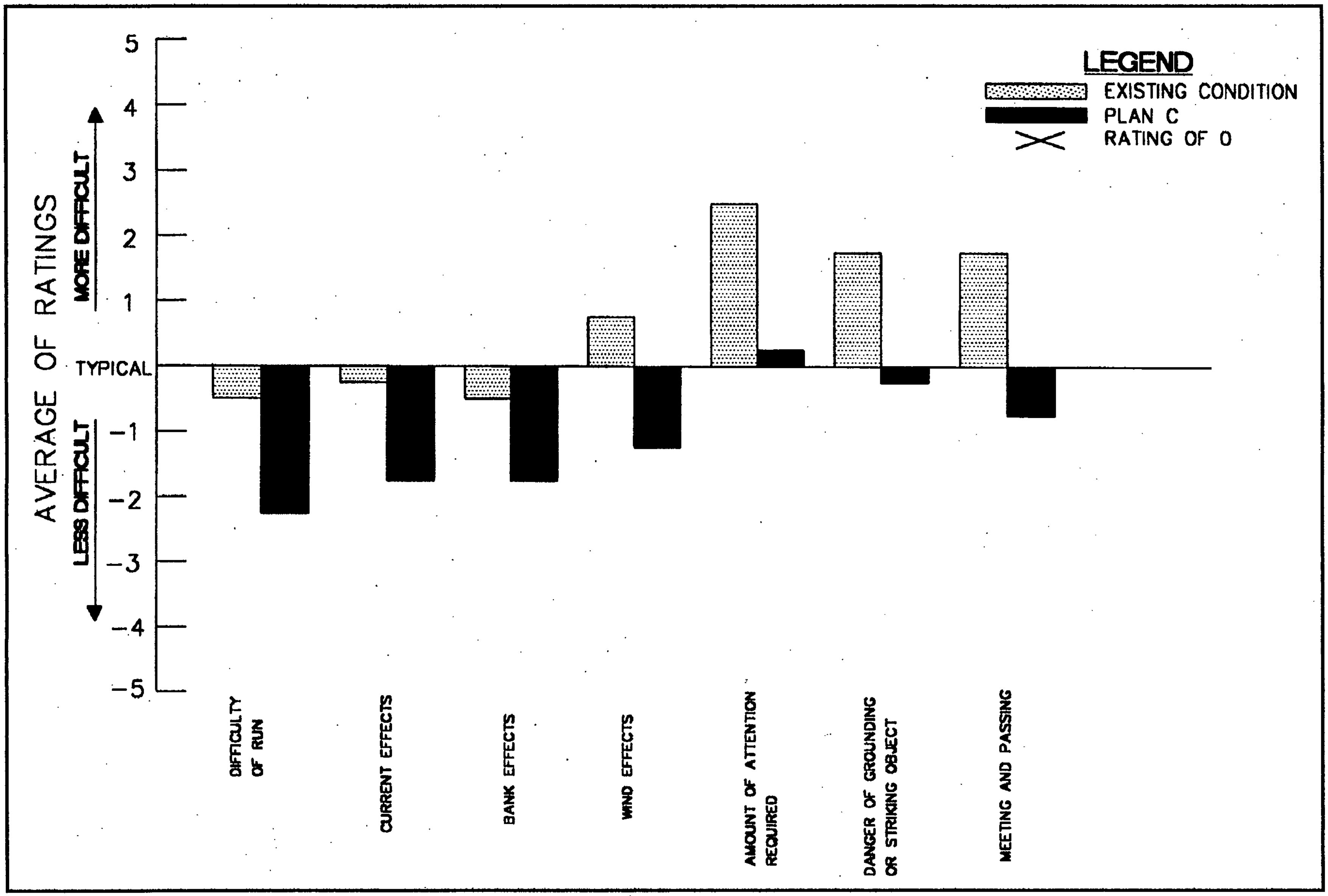

Figure 21. Pilot ratings, St. Johns Bluff, inbound, flood tide

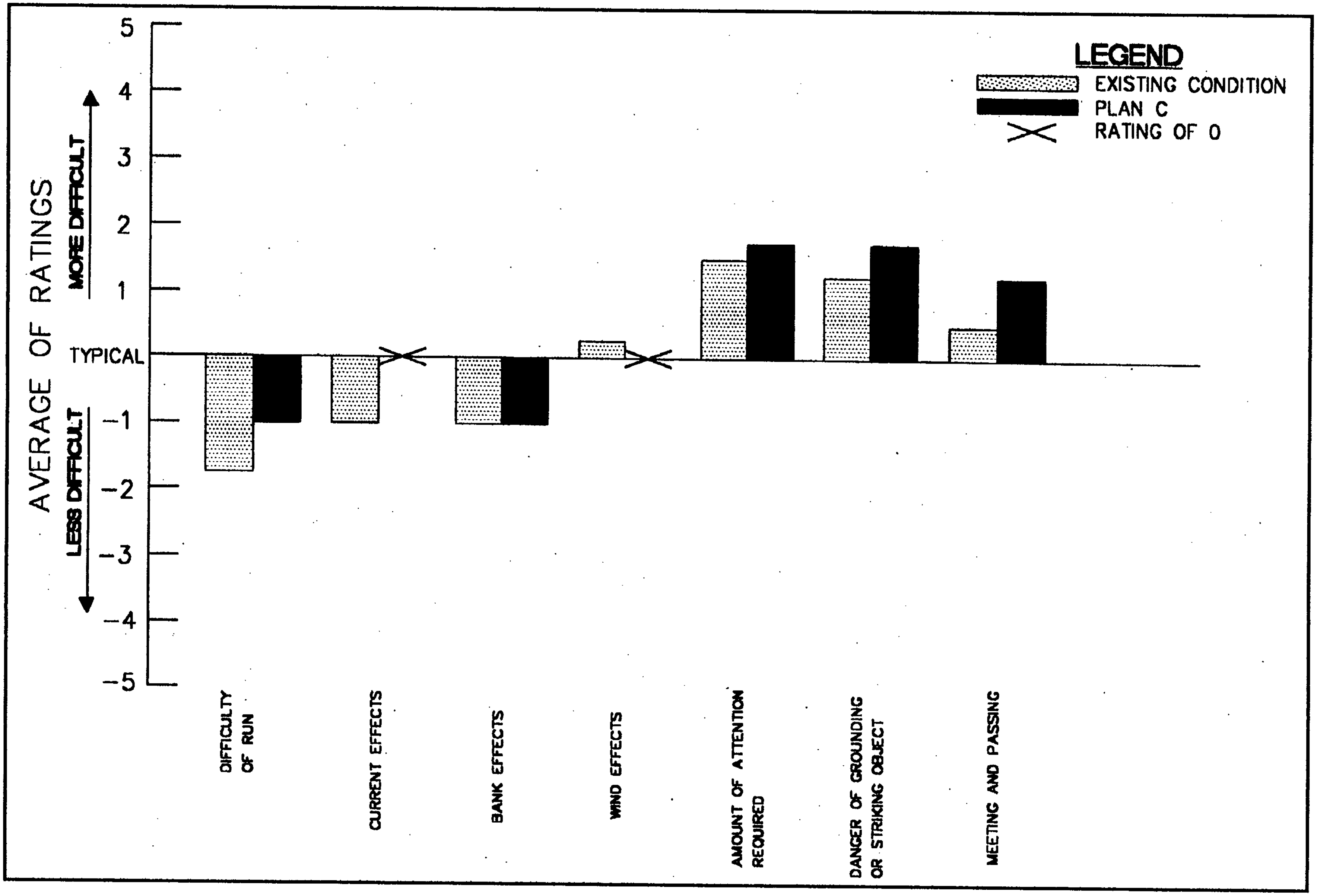

Figure 22. Pilot ratings, St. Johns Bluff, outbound, flood tide

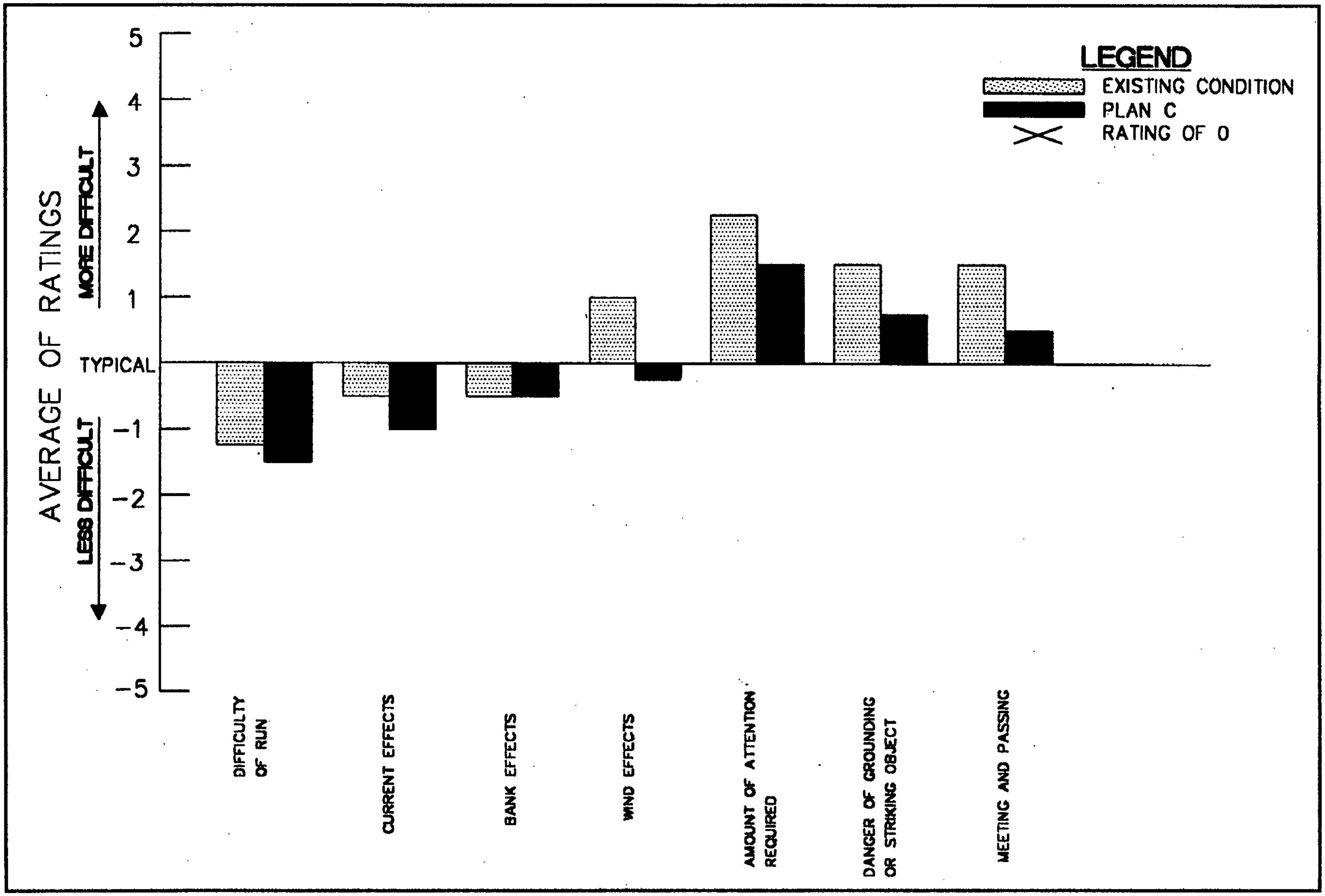

Figure 23. Pilot ratings, Dames Point, inbound, ebb tide

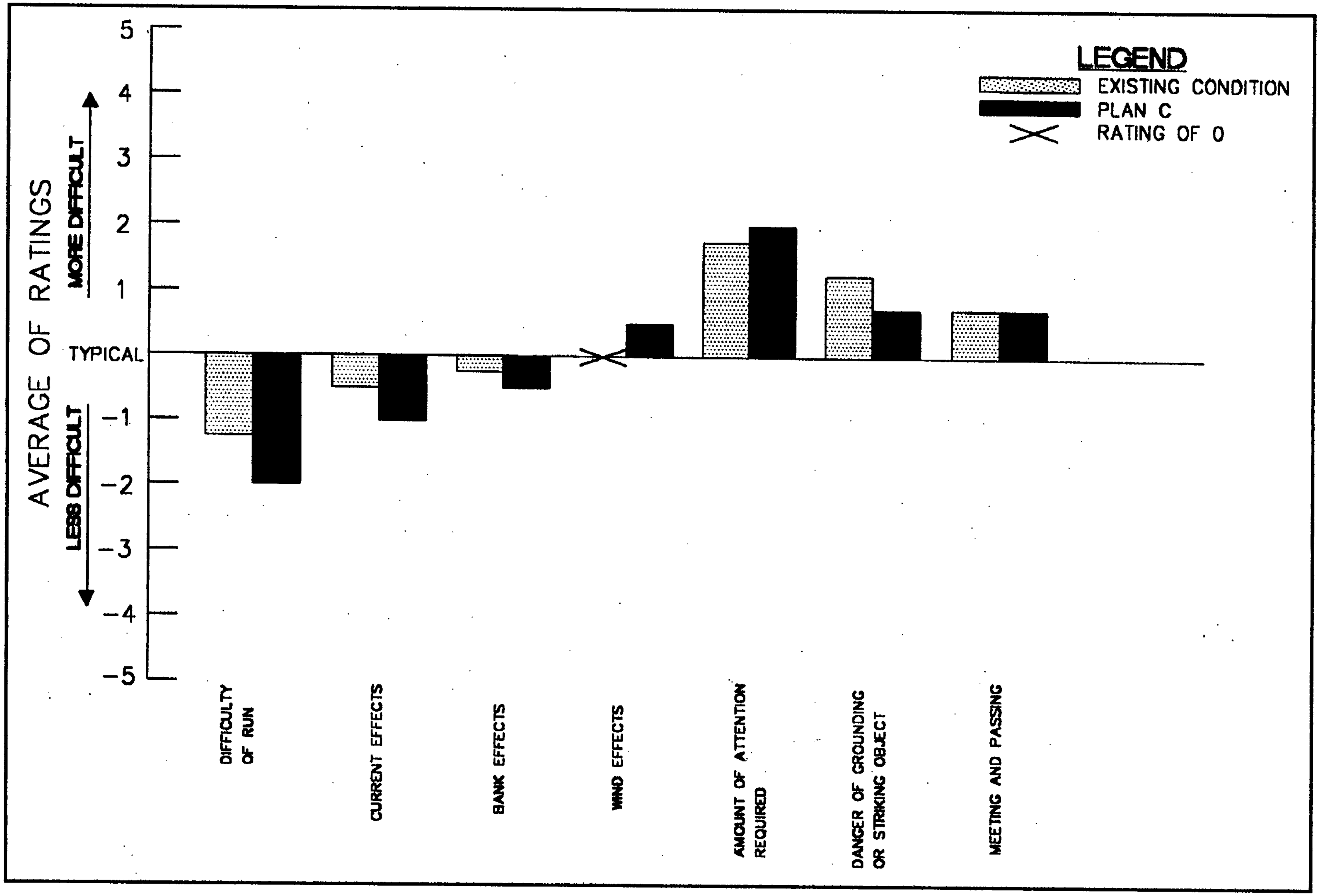

Figure 24. Pilot ratings, Dames Point, outbound, ebb tide

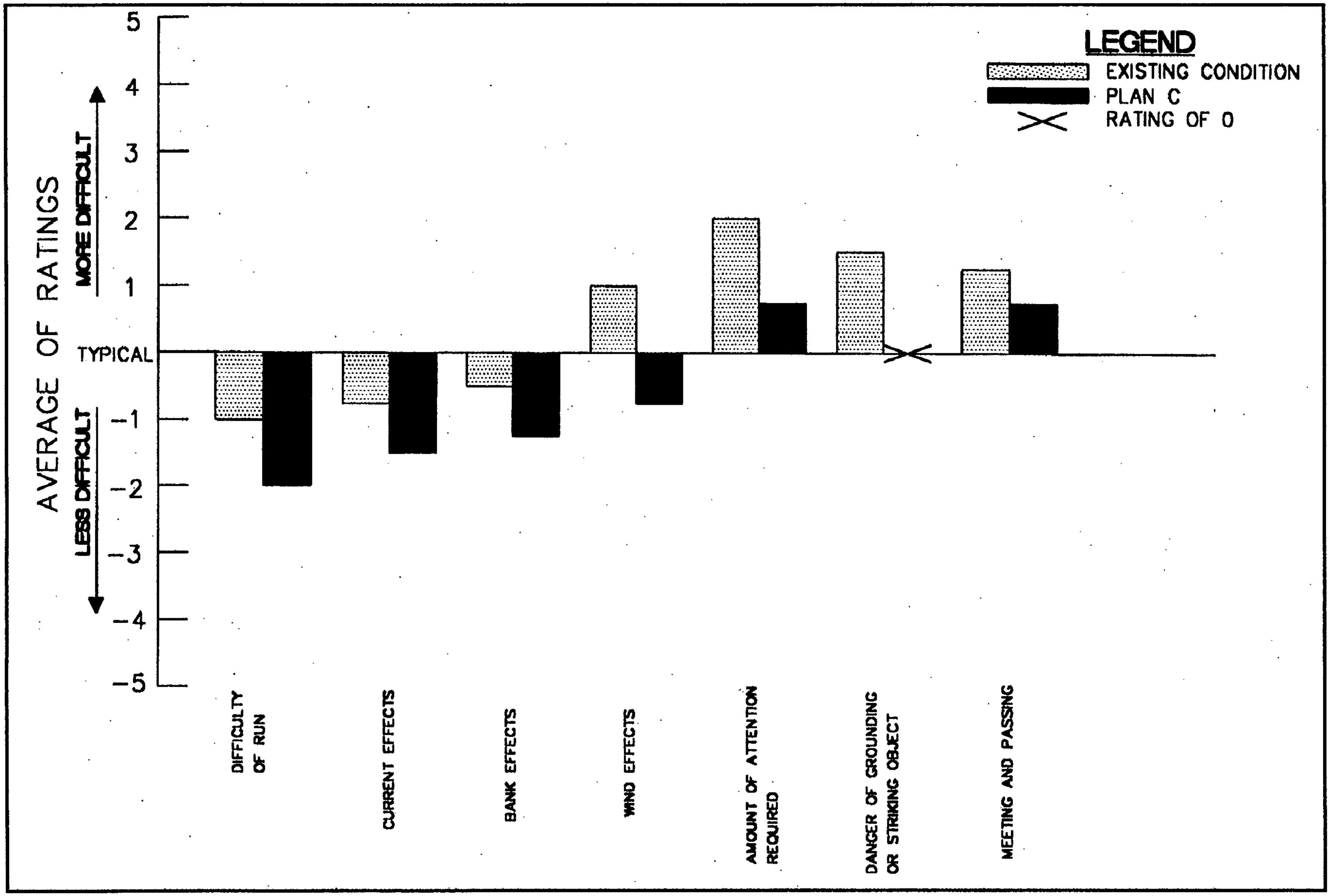

Figure 25. Pilot ratings, Dames Point, inbound, flood tide

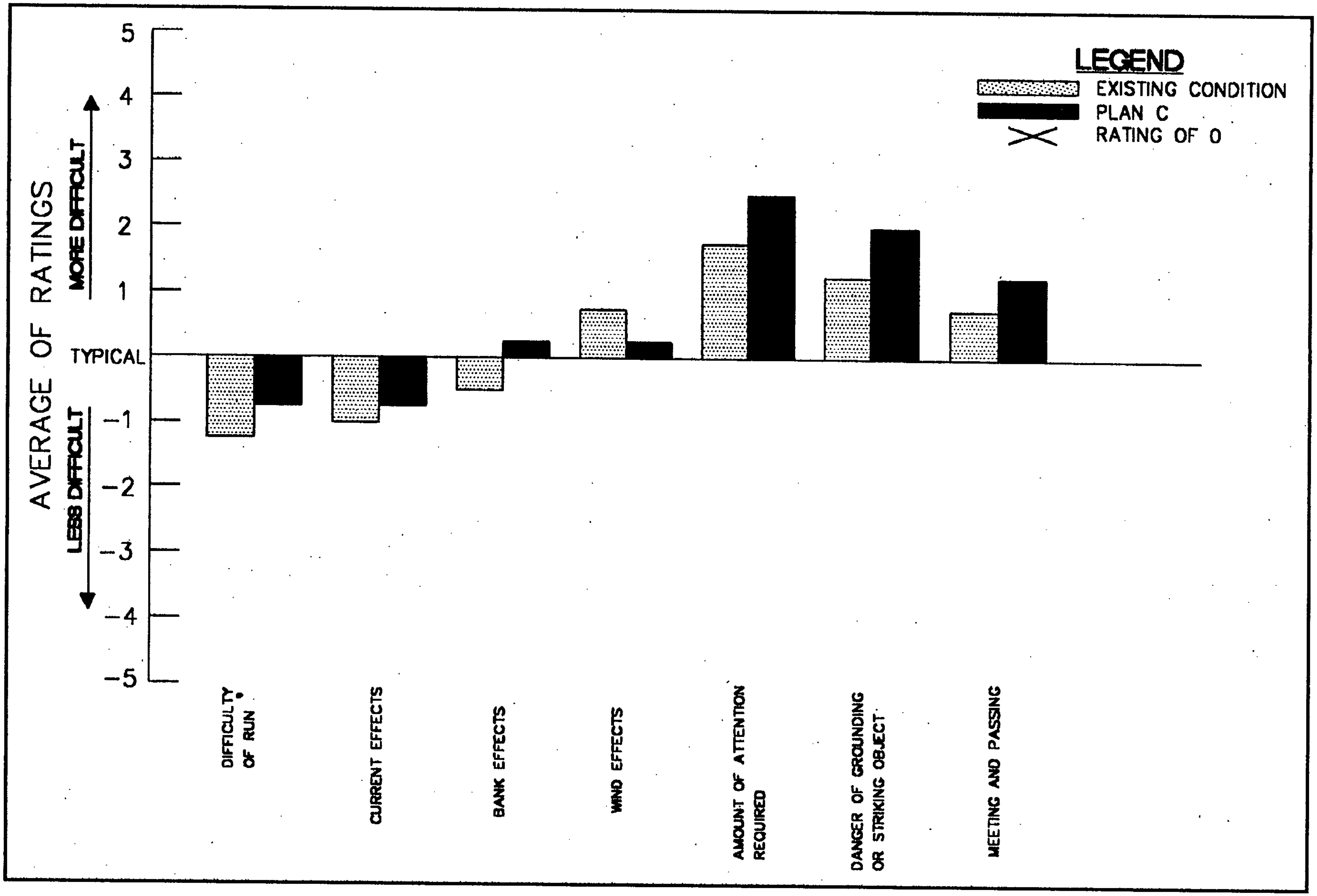

Figure 26. Pilot ratings, Dames Point, outbound, flood tide

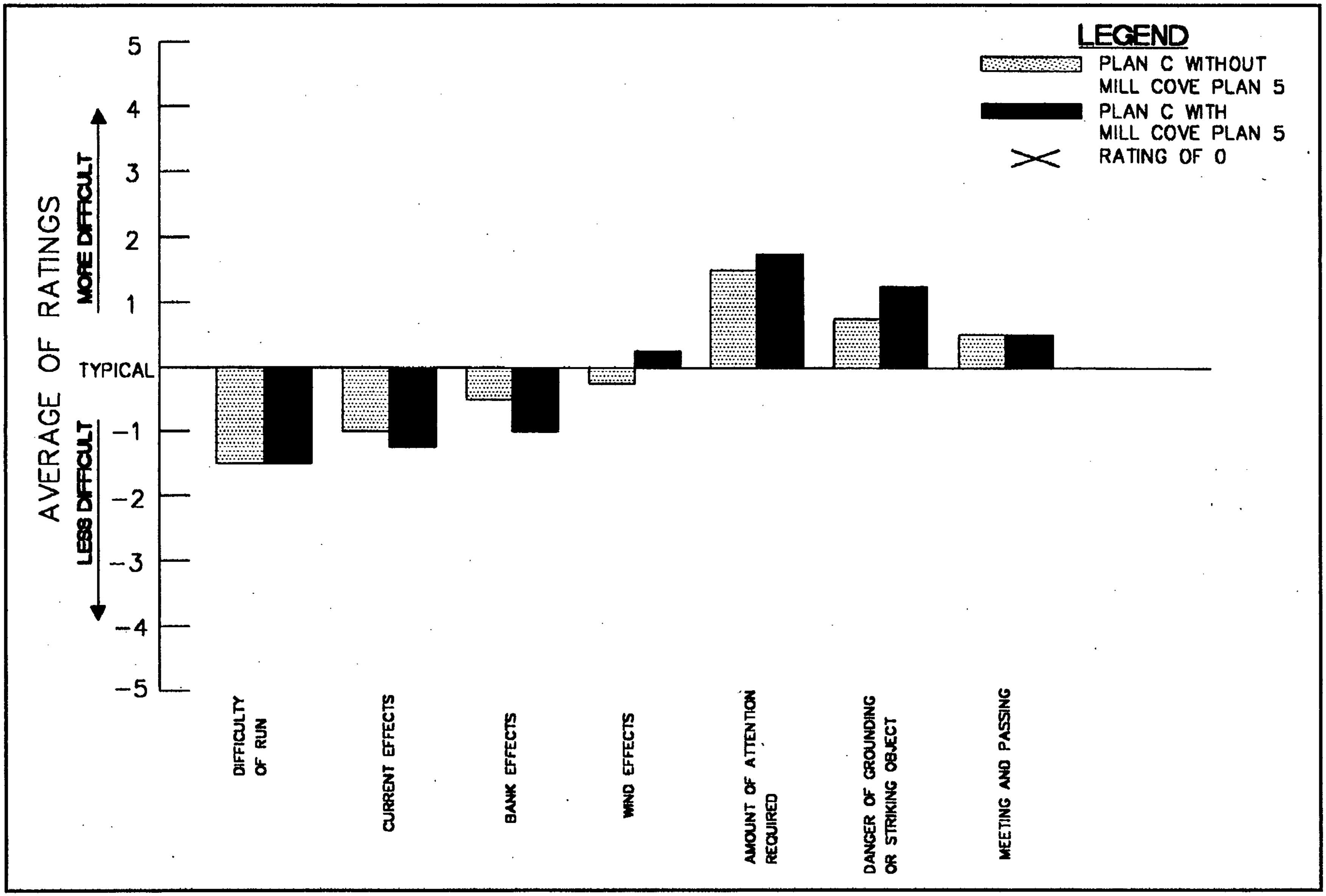

Figure 27. Pilot ratings, Dames Point, inbound, ebb tide

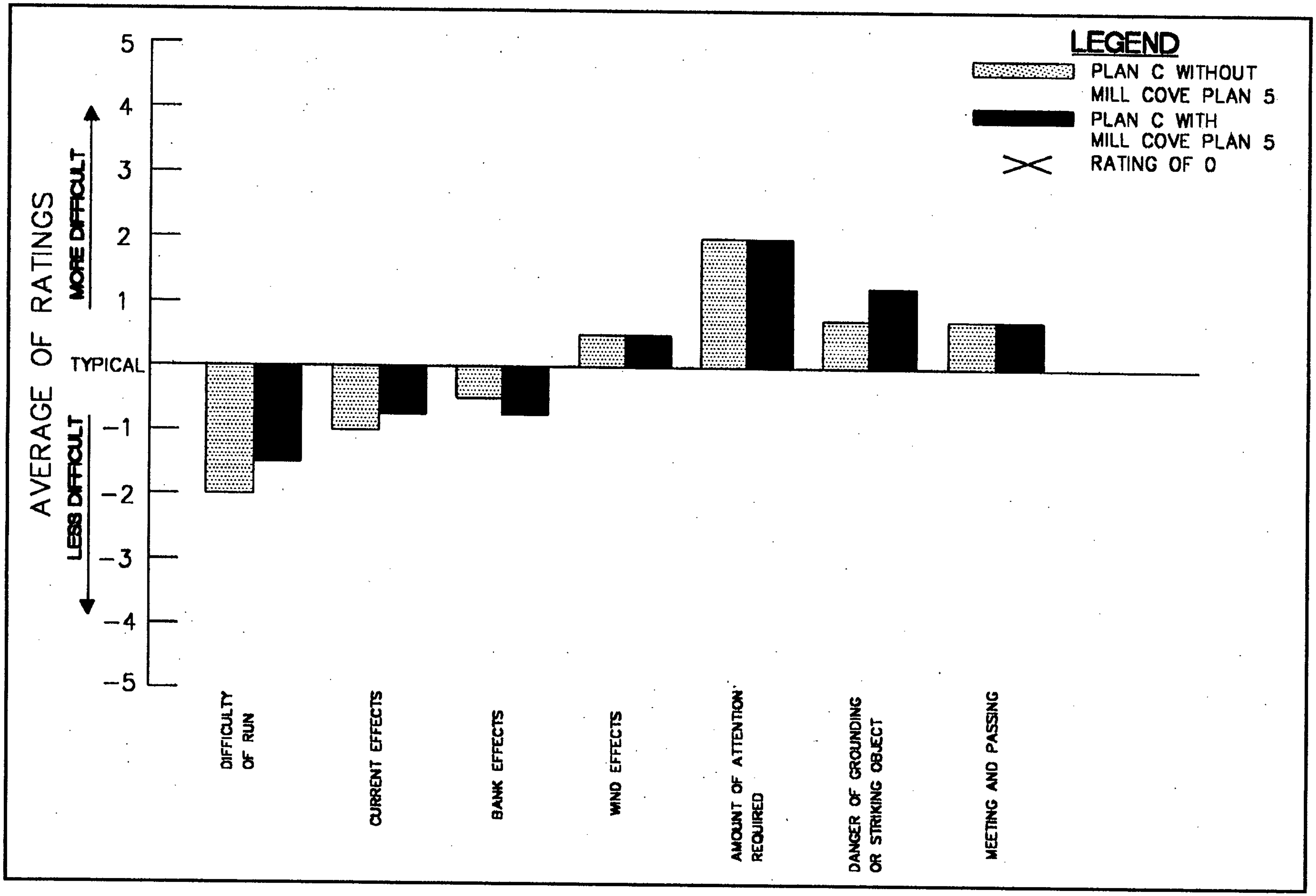

Figure 28. Pilot ratings, St. Johns Bluff, outbound, ebb tide

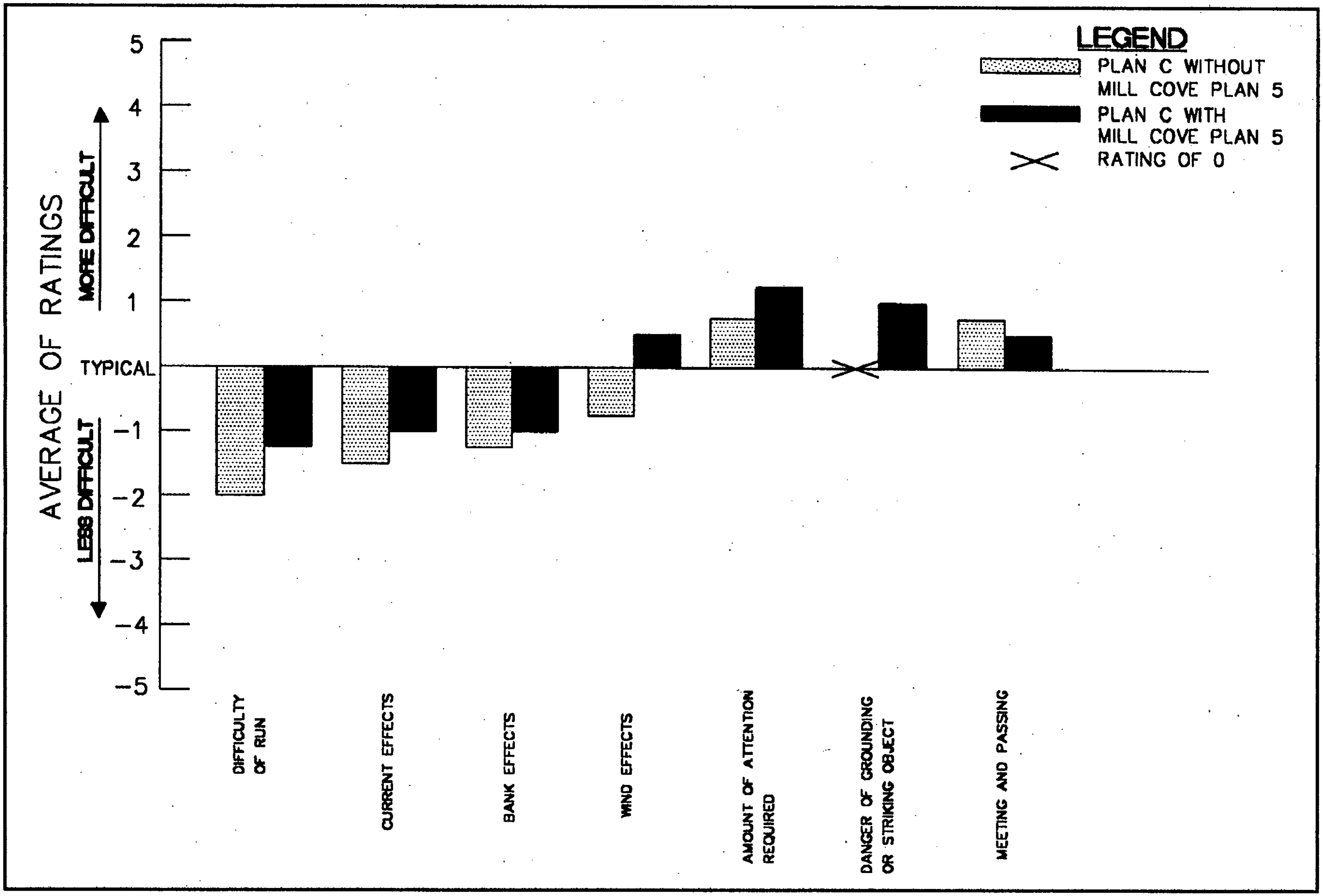

Figure 29. Pilot ratings, Dames Point, inbound, flood tide

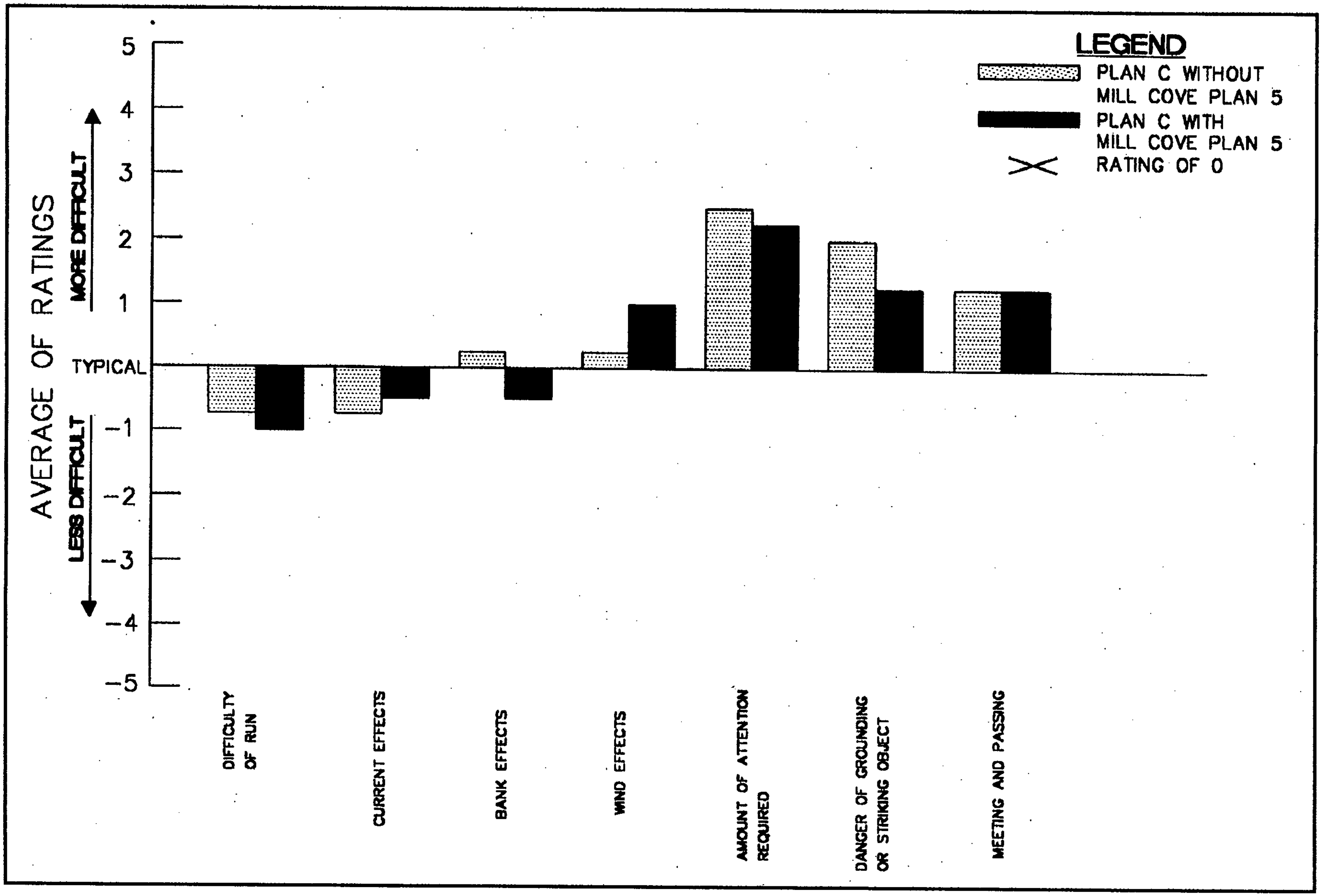

Figure 30. Pilot ratings, Dames Point, outbound, flood tide

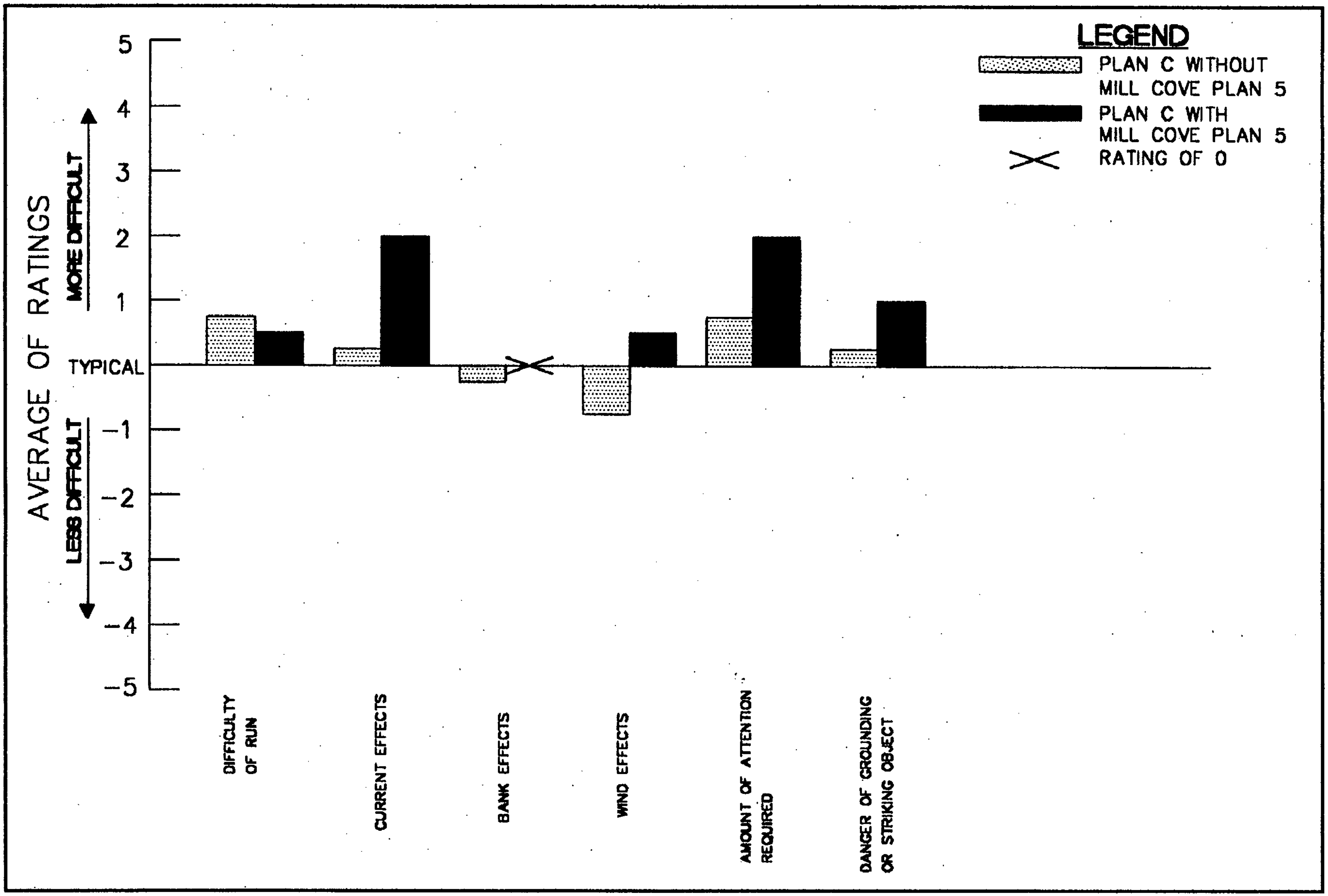

Figure 31. Pilot ratings, Trout River Cut, inbound, ebb tide

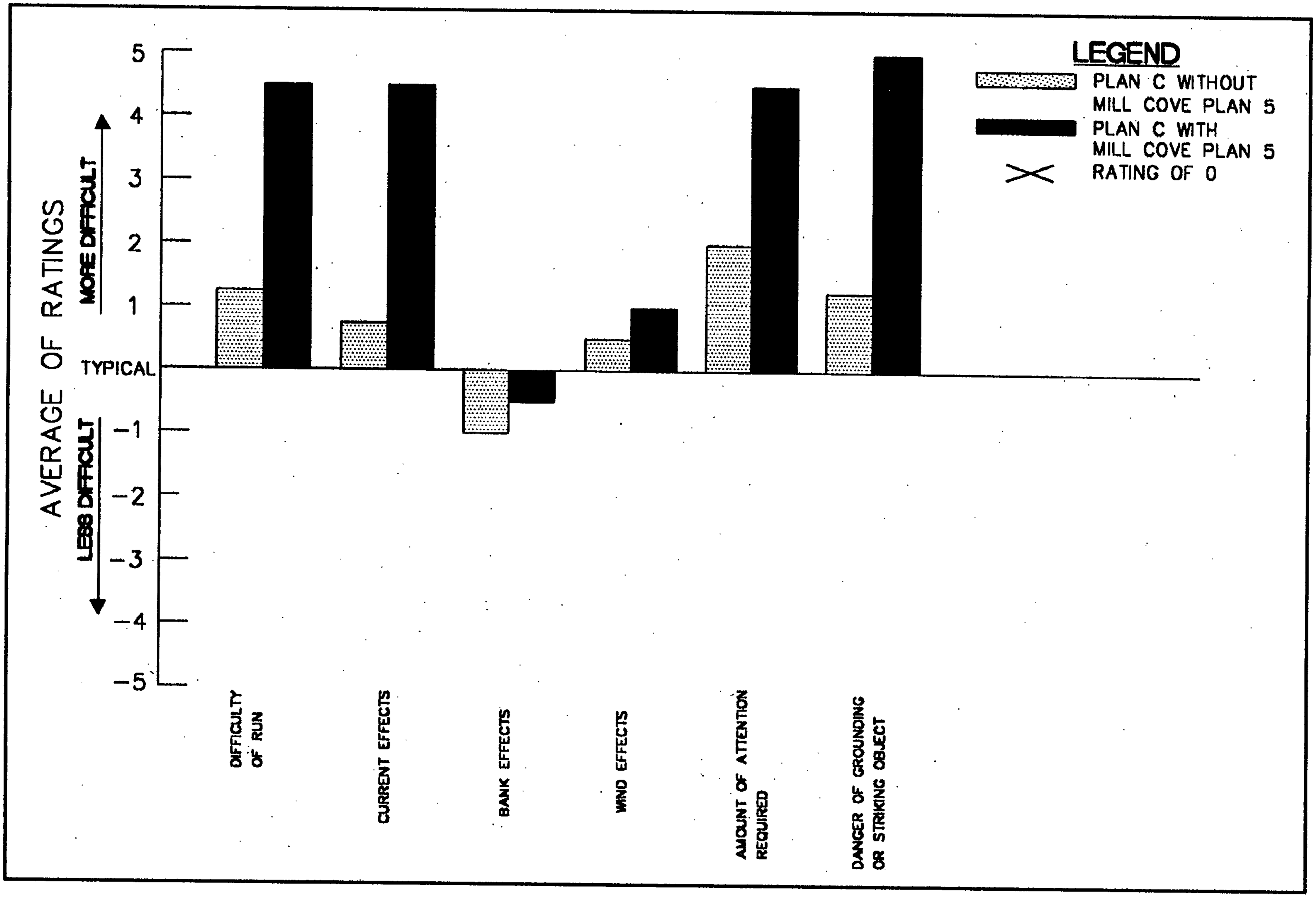

Figure 32. Pilot ratings, Trout River Cut, outbound, ebb tide

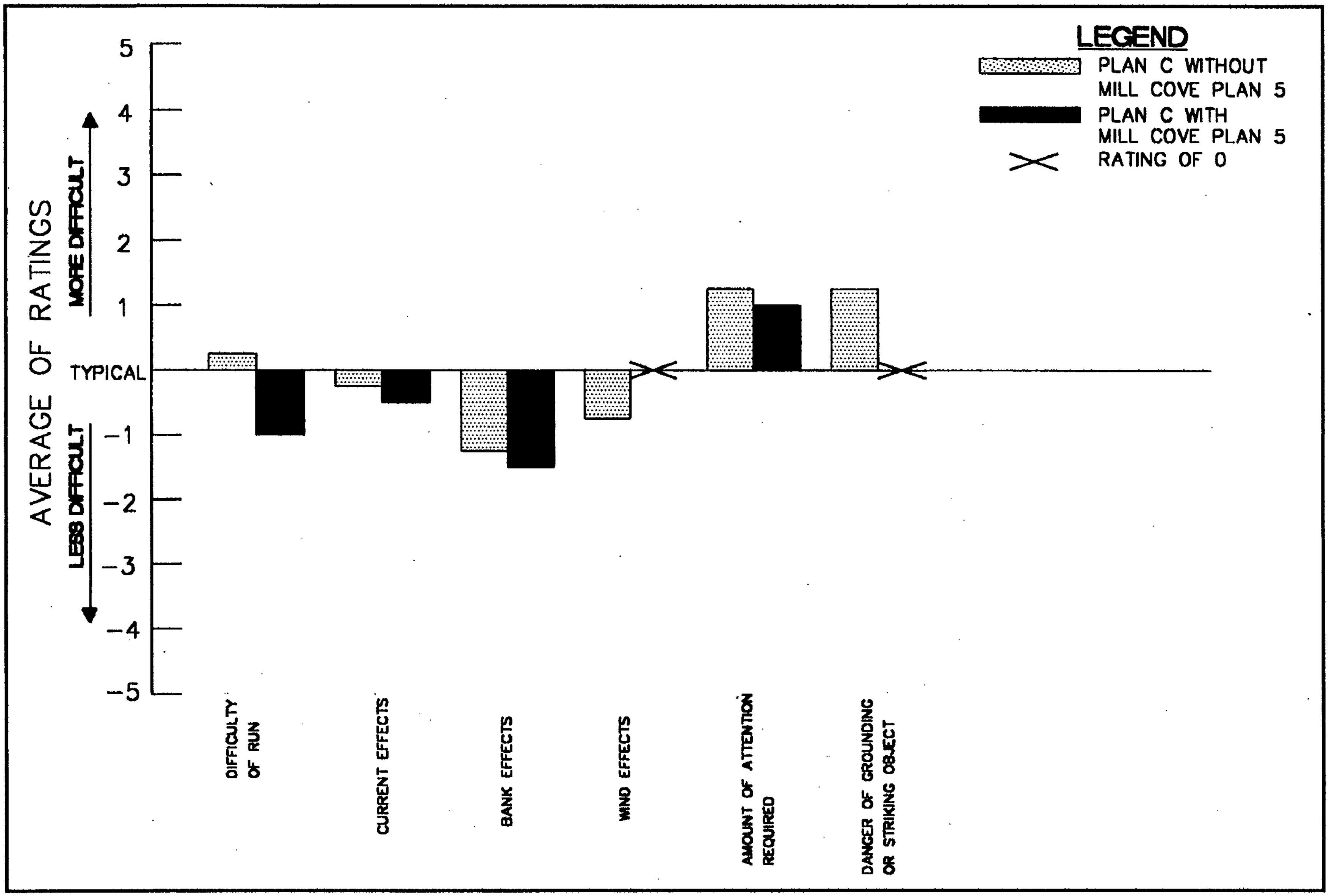

Figure 33. Pilot ratings, Trout River Cut, inbound, flood tide

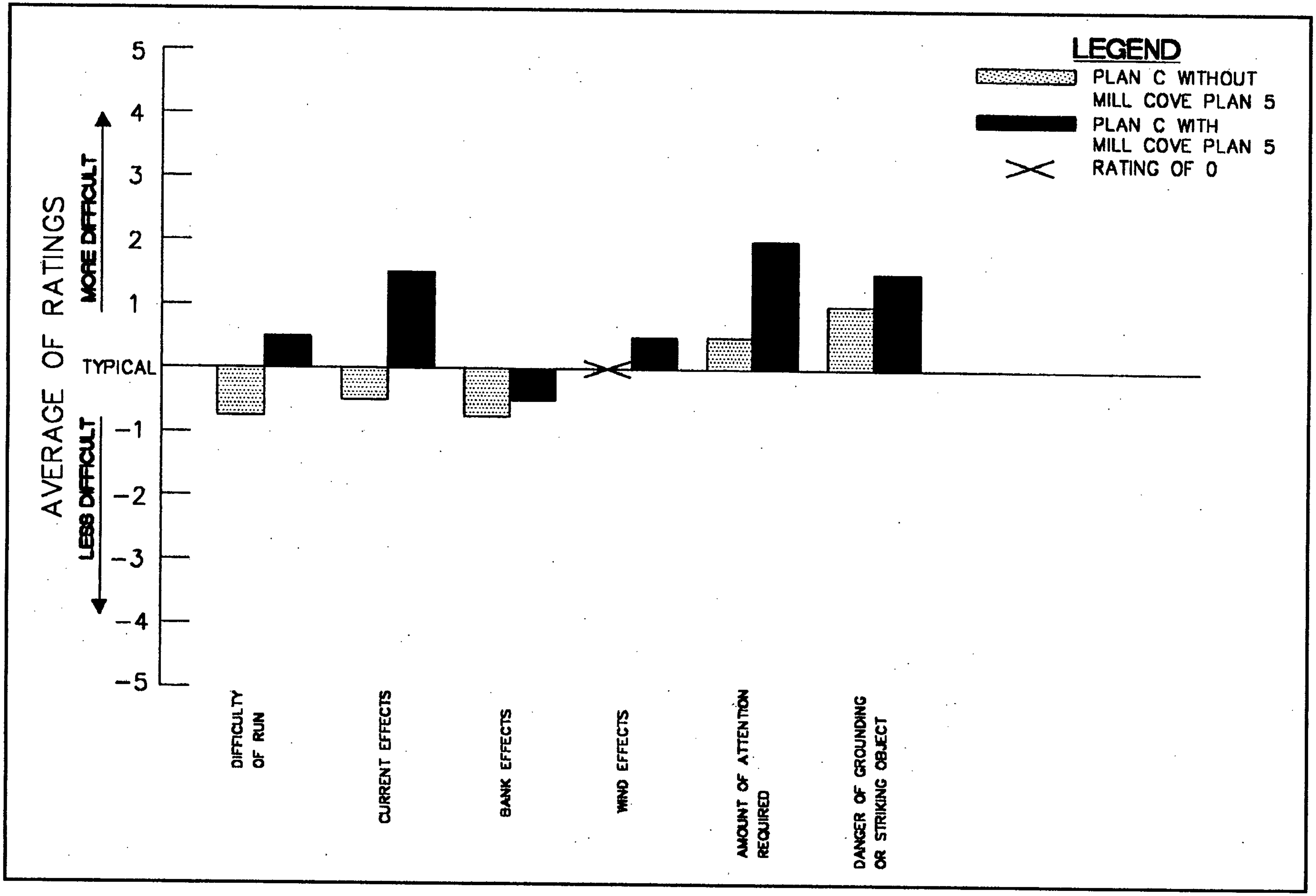

Figure 34. Pilot ratings, Trout River Cut, outbound, flood tide

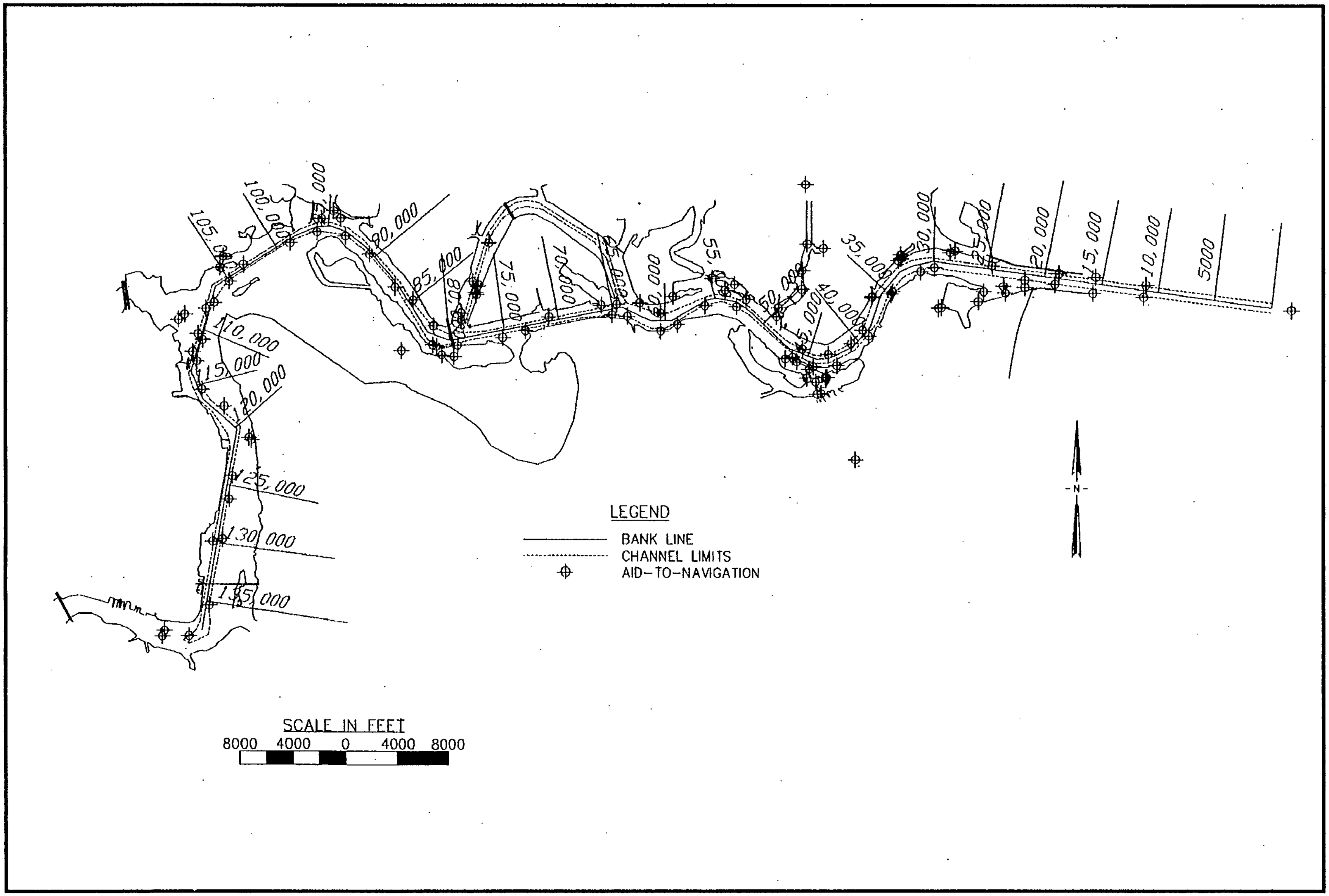

Figure 35. Distance along track

Appendix A Hydrodynamic and Sediment Transport Numerical Modeling of the Jacksonville Harbor Navigation Study

Introduction

Background

The lower St. Johns River is in the northeast portion of the Florida peninsula (Figure A1). The lower river includes approximately 110 miles of tidally influenced river channel with a nominal width that varies from 600 ft to 3.0 miles. Jacksonville Harbor Project extends 24 miles from the Atlantic Ocean to the Acosta Bridge in downtown Jacksonville, FL. A dredged navigation channel (discussed in "Model Results") is maintained from the river mouth to downtown Jacksonville to afford a minimum depth of 38 ft mllw. Two parallel jetties, spaced 1,600 ft apart, stabilize the entrance. At mile 10 a large embayment known as Mill Cove opens onto the main stem of the St. Johns River. Between mile 15 and mile 16 there exists a second, larger opening between Mill Cove and the main stem of the river.

According to Brogdon (1979),

> Tides occurring in the St. Johns River are semidiurnal in nature and have a mean range of about 5.2 ft at the entrance, which diminishes to about 2.0 ft at Jacksonville. The estuary is partially mixed, with differences between surface and bottom salinity concentration at the entrance of about 4.0 to 6.0 ppt. Under the influence of normal tides and freshwater discharge, salinity intrusion extends upstream about 32 miles. The mean tidal range at the entrance is about 4.5 ft; average freshwater discharge is about 4,475 cfs and ranges from negative freshwater inflow

(evaporation exceeds inflows) in the summer months to 9,300 cfs in the winter months.[1]

The Jacksonville District of the Corps of Engineers is seeking to increase the allowable traffic vessel size and improve navigation conditions in the navigation channel of the Jacksonville Harbor. Three plans have been proposed to achieve these goals by increasing the depth and changing the alignment of the navigation channel. In this study a two-dimensional, vertically averaged hydrodynamic model was used to compare the water current velocities that occur in the present-day navigation channel against the water current velocities that would result from the three plan configurations. Sediment transport was simulated using a two-dimensional, vertically averaged model of sediment advection and dispersion in the water column, with the channel bed acting as a source and/or sink for sediment as it deposits and erodes. Two grain sizes were considered in separate simulations: fine sand and medium-grained sand. Only noncohesive sediments were modeled.

The St. Johns River model was applied to study the hydrodynamic and sediment transport impacts of two channel deepening plans, a hydrodynamic study of a third channel deepening plan derived from the previous two, and the hydrodynamic and sediment study of various proposed plans to improve water circulation in Mill Cove. The modeled impacts of the Mill Cove proposed plans are to be reported in a separate Mill Cove hydrodynamic and sediment transport modeling report. The model also produced the water current velocity vectors used in a ship simulator study; these results are reported separately. In the current report, the modeled currents and sediment transport for the navigation channel deepening plans are compared against the existing navigation channel configuration.

Objectives

The objectives of this study were as follows:

a. To investigate the hydrodynamic characteristics of the system by developing a two-dimensional, vertically averaged numerical model of the existing tidal hydrodynamics for the lower St. Johns River, with particular emphasis on the Jacksonville Harbor navigation channel and the Mill Cove area.

b. To investigate the sediment transport characteristics by developing a two-dimensional, vertically averaged numerical model of the existing noncohesive sediment transport in the lower St. Johns River.

[1] Brogdon, N. J., Jr. (1979). "Mill Cove model study: hydraulic, salinity, and shoaling verification," Technical Report HL-79-12, Report 1, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

c. To compare modeled water current velocities for the existing Jacksonville Harbor navigation channel against three engineering plans that involve deepening and realignment of the navigation channel, and provide those currents to the WES ship simulator.

d. To apply the unverified sediment model to compare modeled patterns of noncohesive sediment erosion and deposition under base and proposed navigation channel plans.

Technical Approach

The Jacksonville District is studying the feasibility of increasing the depth of the navigation channel to allow the traffic of larger vessels for future demand and also the improvement of navigation conditions by the realignment of the navigation channel. Three plans have been proposed to achieve these objectives.

In this study, the changes in water current velocities and noncohesive sediment transport that would result if the proposed plans were built were tested using a two-dimensional, vertically averaged numerical hydrodynamic model. The hydrodynamic model used in this study employs the Galerkin finite element formulation to solve the vertically averaged Reynolds form of the Navier-Stokes equations with hydrostatic assumption applied. These equations are commonly known as the vertically integrated shallow water equations. The hydrodynamic model, known as RMA2-WES, was originally written by Dr. Ian King and Mr. William Norton of Resource Management Associates (RMA) in Lafayette, California, under contract to the U. S. Army Corps of Engineers (USACE). The model is maintained and has been enhanced by personnel of the USACE Waterways Experiment Station (WES) in Vicksburg, Mississippi. The version used in this study was RMA2-WES Version 4.295. The sediment transport model, known as SED2D-WES Version 1.05 (formerly STUDH), uses the Galerkin finite element formulation to solve the advection-dispersion equation for total sediment transport suspended in the water column and as bed-load. The channel bed is considered to be either a source or sink of sediment, depending upon the bed shear stress that results from the velocity field calculated by RMA2-WES. This sediment transport model was originally developed by Dr. Ranjan Ariathurai of RMA and has been subsequently maintained and enhanced by personnel of WES.

The numerical models RMA2-WES and SED2D-WES were chosen for this study for several reasons. First, the finite element method permits the modeler to develop an unstructured mesh to define the channel geometry. The lower St. Johns River has many tributaries and secondary channels that are difficult to discretize in the sense of a structured, index based grid. The finite element method uses freely connected three-sided and four-sided elements that are knitted together by means of an element connection table, thus permitting the modeler more flexibility to resolve important geometric features that may be required to accurately compute the flow field. Second, a vertically averaged description of the hydrodynamics was sufficient to answer the questions that were posed concerning the relative impacts of the engineering plans on tidal flushing in Mill

Cove. Third, RMA2-WES has been successfully applied in over 100 estuarine and riverine modeling studies conducted by the USACE. SED2D-WES and its predecessor, STUDH, have also been applied and tested in a variety of studies conducted by the USACE WES.

Hydrodynamic model data

The three Jacksonville Harbor navigation channel plan simulations were compared against a base simulation of the existing 1995 ship channel. The St. Johns River mesh was built using data from a variety of sources. The bathymetric data used to generate most of the numerical mesh was digitized from the National Oceanic and Atmospheric Administration (NOAA) Nautical Charts, National Ocean Survey (NOS) Nautical Chart No. 11491, November 20 , 1993 (27th Ed.), and NOS Chart No. 11492, July 18, 1992 (17th Ed.). The bathymetry of the navigation channel was provided by the Jacksonville District.

The grid for the existing (base) condition (Figure A2) has 9,806 elements, 28,835 nodes, and a maximum element front width of 324. The depths, in reference to the mean lower low water (mllw), range from 0.09 ft along some lateral boundaries of the grid to 80 ft at the jetties. Depths at the offshore boundary are between 50 and 60 ft. Most of the navigation channel is 38 ft deep, except for the Blount Island Channel which is 30 ft, and the Terminal Channel which has an average depth of 35 ft. The average depths in the Mill Cove area are between 1 ft at the eastern end and 4 ft at the western end. The rest of the mesh from Jacksonville to Buffalo Bluff has depths that range between 10 and 20 ft.

The numerical model mesh was carefully designed to address questions of navigation and circulation in the vicinity of the proposed projects. More resolution was added to the navigation channel and adjacent areas than the rest of the grid. This resolution is needed to decrease errors within the study area and to provide a high resolution flow field as input for the ship simulator. The average size of elements in the navigation channel were 500 ft long and 170 ft wide. The computational domain was extended far from the area of interest to ensure that the solution was not unduly influenced by errors in the boundary condition data. Lateral shoreline boundaries were smoothed to improve the accuracy of the mass conservation computations.[1]

The model hydrodynamic boundary conditions were the same for the base and the proposed plans. The water discharge into the system was constant. The tributary stream values (Table A1) were historical means collected from the U.S. Geological Survey Water-Data Report FL-92-1A.

The offshore boundary was defined to be about 4 miles away from the coast line. This boundary condition was applied only on the offshore edge and

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[1] McCollum, R. A., and Donnell, B. A. (1994). "Claremont Terminal Channel, New York Harbor," Technical Report HL-94-14, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Table A1
Tributary Stream Values

Name of Tributary	Stream Discharge, cfs
Ortega River	36.00
Julington Creek	10.70
Black Creek	350.00
Deep Creek	8.47
Rice Creek	192.00
Dunns Creek	161.60
St Johns River at Buffalo Bluff	4,448.00

consisted of a dynamically varying water surface elevation that represents the tidal fluctuations at sea (Figure A3). The tide selected for the runs was the spring tide of 6 October 1994. A period of large tidal range was chosen in order to provide the strongest currents for the ship simulator tests. The period of the initial simulation was 72 hr, starting 1900 on 3 October, which permitted the model to stabilize before the occurrence of the spring tide. This practice is commonly referred to as model spin up. The 72 hr of simulation were divided into half hour time steps. Tide data was obtained from the TIDE 1 database package developed by NOAA. The most convenient tide gauge available to use as a control gauge was the Mayport Station. To apply this tide data to the offshore boundary it was necessary to amplify the tide range slightly, thus keeping the original tide as it reached the Mayport Station.

Hydrodynamic model verification

The parameters available to adjust the model are channel bed roughness and eddy viscosity. The roughness is controlled by means of the correct spatial assignment of the Manning's *n* coefficient values. The assignment of the coefficient values is accomplished by associating a material type with each of the elements in the mesh. Several different material types can be defined to describe the different physiographic regions of the estuary. For this model, the material types represent either regions of a specific range of depth, an area of interest such as navigation channel, or an obstruction to the natural flow of the water. The assignment of material types by depth is equivalent to assigning materials that differ by vegetation cover and bed composition. The eddy viscosity or turbulent exchange coefficients E describe the degree to which small scale turbulent flow features dissipate energy in the flow field. A high eddy viscosity coefficient indicates high levels of turbulent energy dissipation. This parameter accounts for small scale flow features that are not specifically resolved by the numerical mesh. Therefore, the value of eddy viscosity is a function of both the local flow field and the local grid size. As a rule of thumb, eddy viscosity is often assigned according to a grid Peclet number criterion. The grid Peclet number is defined[1] as:

$$P = (\rho\ V\ \Delta x)/E_{ij}$$

where

ρ = density, slugs/ft3

V = velocity along a particular streamline, ft/s

Δx = mesh spacing, ft

E_{ij} = eddy viscosity where i is momentum turbulent exchange in j-direction, lbf•s/ft^2

A Peclet number less than 50 is desirable for numerical stability. This is the criterion that was applied for the assignment of eddy viscosity values in this study. Table A2 shows the resultant roughness and viscosity coefficients assigned for each material type in the St. Johns River numerical mesh. In one case, near the docking facility (material no. 5), an extremely high eddy viscosity value was applied in order to account for the energy dissipation caused by small scale loading and docking facilities that are not explicitly resolved by the numerical mesh.

Table A2
Material Type Properties

Material No.	Exx lbs•s/ft^2	Exy lbs•s/ft^2	Eyx lbs•s/ft^2	Eyy lbs•s/ft^2	Manning's n	Description
1	60	60	60	60	0.024	20-80 ft deep
2	60	60	60	60	0.024	navigation channel
3	60	60	60	60	0.024	navigation channel
4	70	70	70	70	0.031	dock piers
5	100000	100000	100000	100000	0.027	docking facility
6	800	800	800	800	0.024	sea
7	700	700	700	700	0.024	sea
8	400	400	400	400	0.024	sea-channel transition
9	70	70	70	70	0.031	0-4 ft deep
10	70	70	70	70	0.029	4-10 ft deep
11	70	70	70	70	0.027	10-20 ft deep
12	250	250	250	250	0.027	docking facility
13	70	70	70	70	0.04	sea-marsh transition at Little Talbot Island

[1] Brigham Young University. (1994). "TABS Primer," Brigham Young University Computer Graphics Laboratory, Provo, Utah.

The platform used to run the model was a DEC 3000 Model 500 AXP workstation using the Digital Equipment Corporation 21064 RISC processor. On average the simulation required 12 cpu hr to run the 72 hr simulation.

To verify the hydrodynamic model, the results were compared to prototype data collected by WES personnel. The prototype data available include flow discharge and velocity profiles at several river cross sections or ranges during an average time of six hours. There is data available for 5 to 6 ranges for each day during the period of 2 October 1994 to 10 October 1994. Also, the water surface elevation was measured at Mayport and South Jacksonville during the whole period. The spin up time of the model was approximately two days; therefore, real time comparison between the model and the prototype was made for the third day of simulation which corresponds to 6 October 1994 (spring tide).

Tide fluctuations from the model and prototype water surface elevation are compared in Figures A4 and A5. A nearly perfect fit of the model and prototype tidal waves at Mayport was observed. This result was to be expected since the tidal boundary condition was derived from the tidal record at Mayport. At Jacksonville, the tidal signal of the model has a phase lag of about a half-hour when compared to the prototype; the tidal range is practically the same. In general, the tidal wave shape of the model is a satisfactory match to the prototype for the purposes of this study. The differences between model and prototype can be attributed to several causes. First, the river geometry is necessarily simplified for numerical simulation. In particular, the expansive tidal marshes on the north side of the river near the mouth were schematized for the purposes of this simulation. These marshes have a marked if unknown effect on the timing of the tide as it propagates through the system. Second, the tributary flows supplied to the model were historic mean flows, and not synoptic time varying flows for the period of simulation. Several of these tributaries no longer support active gauging stations so that synoptic data was not available for the period of simulation. Last, the effects of winds were not explicitly accounted for in the simulation model. Wind effects were omitted because the objective of this study was to compare the impacts of the proposed plans on tidal circulation in the navigation channel. Winds induce varying effects that depend upon the speed, duration, and direction of the wind field. By choosing one wind field for simulation it is possible that the effects of the navigation channel plans on the tidal circulation could be obscured because wind effects are actually transient in nature.

During spring tide, prototype data was collected at Ranges 24 through 29 (Figure A6). Flow discharges from the model and prototype are compared in Figures A7-A12. The shape of the flow discharge curves at all ranges is close between prototype and model, but in general the prototype has a half-hour delay in phase. For Ranges 25 to 29 there is a shift of the prototype curves to the flood side. This situation is explained by the action of the 15 to 25 mph northeast winds that were present during the day of the survey and increased the flood discharge. According to Brogdon, "Winds have considerable effects on the water level and velocity currents. Strong northerly winds raise the water level about 2.0 ft at Jacksonville; strong winds from the opposite direction lower the water level about 1 ft and may increase or decrease flood and ebb current velocities."[1] At Range 24 the prototype discharge curve shifted to the ebb side, showing higher ebb discharge than the model. The cause for this difference in flow could be that the ebb currents at Drummond Creek Range have the resistance of the northeast winds and find it easier to deviate through Mill Cove. To confirm the statement about the effects of the winds over the currents, peak discharges in other parts of the channel (Figure A6) were compared (Table A3).

Table A3
Model Verification of Maximum Discharges

Range No.	Prototype Date, hr	Max. Prototype Discharge, cfs	Model Time, hr	Max. Model Discharge, cfs	Percent Error	Winds in Prototype, mph
5	10/2/94 (10:20)	229990 (ebb direction)	67.7	230600 (ebb direction)	0.26	10-20 from SW
16	10/4/94 (14:06)	160160 (ebb direction)	68.0	205100 (ebb direction)	28.06	20-30 from NE during morning 15-20 during afternoon
41	10/9/94 (13:45)	142406 (flood direction)	63.0	151000 (flood direction)	6.03	calm during morning light from SE during afternoon

At Range 5 the maximum ebb discharge from the prototype was almost the same as the model value, even when the prototype tidal range was smaller than the model tidal range. Winds on 2 October were in favor of the ebb currents. The prototype ebb discharge at Range 16 was less than the discharge obtained with the model. At the time of the survey, the tidal range was smaller in the prototype than in the model. On 4 October, the winds were in the opposite direction to the ebb current. The day when data from Range 41 was collected had negligible winds and as a result the discharges were as expected; flood discharge in the prototype was slightly less than in the model due to the smaller tidal range of the prototype.

As seen in the above description, wind is an important variable in the complex St. Johns River estuary system. Although the wind forces are not simulated by this model, the water flow discharges through the system were acceptable considering that the tests the model is required to make are fairly insensitive to model adjustment. As expected, the velocities in the model were consistent with a depth-averaged value of the velocities measured in the prototype.

[1] Brogdon, N. J., Jr. (1979). "Mill Cove model study: hydraulic, salinity, and shoaling verification," Technical Report HL-79-12, Report 1, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

Sediment transport model data

The data available for the development of the unverified sediment model was a maintenance dredging map dated 12 November 1993 and historical core boring logs of the navigation channel from 1960 to 1993. Both sources of information were provided by the Jacksonville District. Erosion and shoaling problems were identified by District personnel. Based on the information provided, the predominant bed material in the navigation channel was determined to be fine- to medium-grained sand.

Sediment transport model development

The state of the art in cohesive sediment transport modeling is such that extensive field data are required to verify a model and to define the sediment properties. The data collection effort required to perform a cohesive sediment modeling study was beyond the scope of this project. Noncohesive sediment modeling was used to determine whether the proposed navigation channel deepening plans would induce significantly different sediment transport behaviors than are observed under the existing conditions.

Two runs were made for the existing condition and each of the first two plans. One run considered sand grains 2.625×10^{-4} ft in diameter (fine-grained sand), while the other run considered sand grains 6.562×10^{-4} ft in diameter (medium-grained sand).

The initial bed condition for the sediment study was a sand bed of uniform thickness over the mesh. This is not a realistic condition because in reality the sand bed varies in thickness over the estuary. However, this initial condition permits the modeler to observe the potential rates of erosion that would occur given an infinite supply of sand from the bed. This approach is useful when comparing the potential for erosion between existing and plan conditions. The result is that erosion will be overestimated when compared with the prototype, which has a limited supply of sediment from the bed, but the comparisons between existing and plan conditions will be consistent.

The model was verified by adjusting the roughness and fall velocity of the sand particles on a regional basis. The modeled sediment erosion and deposition patterns were found to be qualitatively similar to those observed in the prototype. The roughness of the sand grains is described by the effective Manning coefficient. The roughness values used were between 0.001 in the navigation channel to 0.027 on the banks of the river. The fall velocity for the fine-grained sand was 0.0082 ft/s and 0.066 ft/s for the medium-grained sand.

The sediment simulation period was 15 days and 15 hr. The flow field used to drive the sediment transport model was generated by RMA2-WES. A limitation of the SED2D-WES model is that the sediment computations are effectively decoupled from the hydrodynamic computations. This limitation can be overcome by periodically updating the hydrodynamic flow field. In other words, any changes in the flow field that would occur due to erosion or deposition of the channel during the SED2D-WES run require the RMA2-WES model to be run again with the new channel bathymetry applied. It was determined through model testing that the rates of erosion and deposition in the St. Johns River would permit the sediment transport model to be run for approximately three days before updating the RMA2-WES flow field. The sequence of simulation for running the sediment transport model was as follows:

a. *Step 1.* The hydrodynamic model, RMA2-WES, was run for 72 hr to develop a realistic flow field. The boundary conditions applied were the same as those described for the verification of the hydrodynamic model. The bathymetry for this model run was the original bathymetry developed from the navigation charts.

b. *Step 2.* The flow field resulting from Step 1 was used as an initial condition for an RMA2-WES simulation with the 19-year mean tidal elevation signal applied at the ocean boundary. This tidal signal was obtained from the Tide Tables 1982, High and Low Water Predictions, published by NOAA. The tidal signal was repeated for the duration of the simulation period, which was 3 tidal days or 75 hr. The bathymetry for this model run was the original bathymetry.

c. *Step 3.* The sediment transport model, SED2D-WES was run using the flow field developed in the preceding RMA2-WES run. The simulation period for this SED2D-WES run was 3 tidal days or 75 hr. The bed of the estuary was allowed to erode and deposit sediment as dictated by the model equations. At the end of the run, a new bathymetry file was saved reflecting the bed changes that occurred during 3 tidal days of sediment simulation.

d. *Step 4.* The flow field generated by the previous RMA2-WES run was used as an initial condition for a new RMA2-WES simulation using the 19-year mean tidal elevation signal at the ocean boundary and the bathymetry derived from the previous SED2D-WES run. The duration of the new RMA2-WES simulation was 3 tidal days.

e. *Step 5.* Steps 3 and 4 were repeated until a total of 15 tidal days of sediment transport simulation were accomplished. The final product of this simulation is a map of net bed change over the 15-day simulation period.

Model Results

Base versus plan hydrodynamic model results

The purpose of the three proposed plans is to increase the allowable traffic vessel size and improve navigation conditions in the navigation channel of the Jacksonville Harbor. The minimum depth of the navigation channel for each of the three proposed plans is 42 ft. In Plan A the increase in depth is achieved by extending the sides of the channel further down without changing the slope. The navigation channel becomes narrower than before in some places by keeping the original slope. Plan B is based on Plan A, but the width of the channel is restricted to a minimum of 575 ft. Some portions of the actual navigation channel have a minimum width of 400 ft. The last proposed plan, Plan C, is a combination of the previous two plans plus some extra modifications. Plan C is composed of the downstream section of Plan B and the upstream section of Plan A; both sections are connected at Dames Point Turn (Figure A13). The bend where St. Johns Bluff Reach and White Shells Cut Range are connected is straighter than other plans. Trout River Cut Range is wider than Plan A and the original minimum width of 375 ft is 450 ft in Plan C. In Plan C, the minimum width of the Chaseville Turn is 615 ft, 140 ft more than in Plan A. Finally, a turning basin with a minimum width of 1,340 ft in the connection of the Long Branch Range with the Terminal Channel is included in Plan C.

The modeling of Plan C was done in combination with the proposed Plan 5 of the Mill Cove study (Figure A14). This plan consisted of obstructing the natural path of the water at the north of the cove by means of the construction of three closures. The first closure is at the west opening between the Quarantine Island and an island used as spoil area. A second closure is applied between Quarantine Island and William Island. The last closure takes place between the east end of Quarantine Island and Marion Island. Other features of Plan 5 are the addition of a water circulation channel and the shallowing of some areas. The circulation channel is mainly located south of the cove and extends from the northeast opening to the west opening of the cove. At the western opening, the channel is 12 ft deep, 650 ft wide, and 3,800 ft long. At the northeast opening, the channel is 12 ft deep, 1,300 ft wide, and 3,400 ft long. The rest of the circulation channel is 6 ft deep and 80 ft wide. The north part of the cove was made shallower in the model by gradually decreasing the depth between the circulation channel and the northern coastline. In general, the depths at the north are less than 3 ft mllw.

RMA2-WES permits the user to specify a list of nodes for which summaries of the output will be printed. The output summary is a time history of the Cartesian velocity components and the water surface elevation over the period of simulation. Twenty-one time history nodes were located in the navigation channel to measure differences in the computed velocities and the computed water surface elevations caused by the experimentation of the three plans. Nodes were located at each straight section and turn of the navigation channel. For convenience, station numbers will be used for reference instead of node numbers. In addition, continuity check lines can be specified at various cross sections in order to calculate the discharge across the check line at each time step of simulation. Continuity checklines (Ranges 24, 35, and 36) were placed at three openings of Mill Cove into the main river in order to detect changes in the volume of water flowing through the cross section. A close look at the numerical mesh used for the modeling is presented in Figure A15.

The magnitude of total velocity and the water surface elevation at each station for every model run are plotted in Figures A16 through A57. Plots of the water discharge through Ranges 24, 35, and 36 are presented in Figures A58 to A60. Figures A61 and A62 display velocity contour maps of the ebb and flood discharges during existing conditions.

Plan A

At the transition of the Terminal Channel with the Long Branch Range (station 20), a reduction of 7.5 percent in the magnitude of the maximum ebb velocity occurred from the base to the plan. At station 21, located in the Terminal Channel, the maximum ebb velocity increased by 6.5 percent. The rest of the navigation channel experienced changes in velocity magnitude no greater than 5 percent.

The water surface elevation did not change considerably throughout the river. The minimum water surface elevation decreased approximately 1 in. upstream from the western entrance of Mill Cove. The maximum flood water discharge and maximum ebb water discharge through Range 36, located at the western entrance to Mill Cove, decreased by 2.0 percent and 5.1 percent, respectively. There was no considerable change in the discharges across Ranges 24 and 35.

Plan B

The magnitude of the maximum ebb velocity decreased by 5 percent at Drummond Creek Range (station 15) due to the widening of the navigation channel. A reduction in maximum ebb and flood velocities of 12 percent and 10.4 percent occurred at Chaseville Turn (station 18) also as a result of the widening. In actuality, pilots from the Jacksonville Harbor have been experiencing difficulties during ebb tide when navigating this part of the channel. The decrease in velocities will improve navigation conditions. Station 20, located at the union of Terminal Channel with Long Branch Range, experienced a reduction of 6.0 percent in maximum ebb velocity. The maximum ebb velocity in the Terminal Channel (station 21) increased by 8.4 percent. The behavior of the velocities at stations 20 and 21 were similar in Plans A and B. In Plan A, changes in velocity magnitude throughout the rest of the navigation channel were less than 5 percent.

The minimum water surface elevation in the navigation channel upstream from Mill Cove decreased approximately 1.5 in. Reductions in the maximum discharges through Range 36 also occurred in Plan B. The reductions in maximum discharges were 5.2 percent and 9.7 percent for flood and ebb, respectively.

Plan C with Mill Cove Plan 5

The maximum velocities at the transition between St. Johns Bluff Reach and White Shells Cut Range (station 8) increased during ebb and flood by 5.9 percent and 11.4 percent, respectively. The navigation channel at this location was straighter and narrower than in other plans. The maximum flood velocity decreased by 13.5 percent at Dames Point-Fulton Cutoff Range (station 11) as a result of the application of Plan 5 in Mill Cove. An increase of 5.6 percent in the maximum flood velocity occurred at the transition between Brills Cut Range with Quarantine Island Upper Range (station 13). The partial closure of the western entrance to Mill Cove created an increase in the maximum velocities at Drummond Creek Range (station 15); the increases were 6.7 percent for ebb velocity and 8.2 percent for flood velocity. Considering the results of the Mill Cove sediment transport modeling study concurrently done with this navigation channel deepening study, there is a potential for erosion of the river banks and shoaling in the navigation channel at Drummond Creek Range due to the closure. An increase of 5.4 percent in the maximum ebb velocity at the upstream section of Drummond Creek Range (station 16) confirms this. The maximum ebb velocity at Trout River Cut Range (station 17) decreased by 5.2 percent. Maximum velocities at the union of Long Branch Range with Terminal Channel (station 20) decreased by 12.8 percent and 5.0 percent during ebb tide and flood tide, respectively. These reductions are larger than the ones created by the previous two plans. The construction of a turning basin at this location is the cause for the decrease in velocities. At Terminal Channel (station 21), velocities were similar to the ones created by Plans A and B; the increase in maximum ebb velocity was 7.0 percent. Changes in velocity throughout the rest of the channel were less than 5 percent.

The water surface elevation did not experience any considerable change between proposed plans and existing conditions. Inclusion of Plan 5 of the Mill Cove study into the modeling of Plan C created too many external variables to the proposed navigation channel deepening plan. Therefore, Plan C cannot be directly compared to plans A and B with respect to changes in maximum discharges at Ranges 24, 35, and 36.

Base versus plan sediment model results

In this section the results of the fine-grained sand and medium-grain size sand runs are presented. In general, runs made using medium-grained sand were representative of the fine-grained sand erosion patterns but on a smaller scale because of the reduced mobility of the larger grained sediment. Table 4 presents the simulated sediment deposition at different sections of the navigation channel. The model simulated sediment erosion at four locations of the river coastline. These locations, identified by personnel of the Jacksonville District, are of interest because of the unknown effect the proposed plans could have on the actual erosion rates. Table A5 presents the simulated erosion during existing conditions and the change in erosion rate caused by the proposed plans. Figures A63 and A64 show contours of the bed change as a result of the sediment runs during existing conditions. Figures 65 through 82 show plots of the sediment deposition rate changes displayed in Table 4 and Figures A83 to A86 present sediment erosion rate changes from Table 5. The scope of this study did not include a sediment transport model for Plan C.

Sediment deposition in the navigation channel

All the sediment model runs showed a decrease in deposition at Pilot Town Cut Range and the west section of St. Johns Bar Cut Range. The most notable decrease in deposition rate was 11 percent between the existing conditions and Plan A when simulating fine sand. When running the medium sand model of Plan A, an increase of 10 percent occurred in sediment deposition rate at Mile Point Lower Range and Turn; Plan B decreased deposition by 6 percent. From Short Cut Turn to St. Johns Bluff Reach, the rate of deposition increased when modeling the proposed plans. The larger increase occurred when modeling medium sand with Plan A at St. Johns Bluff Reach, where the deposition was more than two times the original value.

There is concern about the excessive sediment deposition being created during existing conditions in the eastern section of the Fulton-Dames Point Cutoff Range. The deposition rate of medium sand at this location increased more than 50 percent when applying Plan A; Plan B decreased deposition by 5 percent. From Dames Point Turn to Brills Cut Range, a considerable increase of 23 percent in medium sand deposition occurred when running Plan A. Plan B showed a decrease in fine sand deposition and a negligible decrease in medium sand deposition in this part of the channel. The sediment results of Plan A were mixed from west of Brills Cut Range to Long Branch Range. There was moderate reduction in sediment deposition of both grain sizes and some considerable increases in medium sand deposition. On the other hand, Plan B caused a large overall reduction in deposition of fine and medium sand in this section. Contrary to most of the results above, Plan A reduced more fine sand deposition in the Terminal Channel than Plan B. On average, Plan B reduced sediment deposition throughout the navigation channel, while Plan A showed mixed results. These results are summarized in Table A4.

Erosion problems

The erosion rate considerably decreased at the northern coastline of the St. Johns Bar Cut Range when applying both plans, Plan A having the greater reduction. As mentioned in the previous section, sediment deposition in this part of the navigation channel decreased also. Therefore, coastline erosion is an important source for sediment deposition in this part of the navigation channel. At White Shells Cut Range all the proposed plans increased sediment erosion of the southwestern coastline, but Plan B eroded the most. The results of the model did not show any strong effect of the proposed plans in the other two erosion sites. In general, Plan A decreased the net sediment erosion from the four erosion sites more than did Plan B. These results are summarized in Table A5. Note that this is an unverified sediment model; therefore, the results have to be interpreted as a potential for deposition or erosion, not as the exact values.

Table A4
Simulated Sediment Deposition in the Jacksonville Harbor Navigation Channel

Location	Sediment Deposition, Existing Conditions, ft		Sediment Deposition, Plan A Rate Change, percent		Sediment Deposition, Plan B Rate Change, percent	
	Fine Sand	Medium Sand	Fine Sand	Medium Sand	Fine Sand	Medium Sand
St Johns Bar Cut Range, West Section - Pilot Town Cut Range	0.32	0.040	-11.4	-3.9	-7	-3.4
Mayport Cut Range- Sherman Cut Range	0.22	0.046	0.3	0.7	1.2	0.7
Mile Point Lower Range and Turn	0.20	0.039	2.8	10.2	3.7	-6.1
Training Wall Reach	0.16	0.046	2.1	-1.4	-0.4	-2.9
Short Cut Turn	0.16	0.012	0.8	18.6	1	40.7
White Shells Cut Range	0.12	0.002	5.7	50	5.3	50.0
St. Johns Bluff Reach	0.14	0.004	6.2	124.1	-1.2	20.7
Fulton-Dames Point Cutoff Range (East)	0.16	0.030	7.7	51.7	-5	0.0
Fulton-Dames Point Cutoff Range	0.12	0.003	5.4	0	-6.5	0.0
Fulton-Dames Point Cutoff Range (West)	0.16	0.002	7.4	0	0.3	0.0
Dames Pt Turn - Brills Cut Range	0.27	0.024	6.8	23.6	-9.0	3.3
Brills Cut Range (West) - Broward Point Turn	0.13	0.011	-5.2	-4.5	-16.4	-54.5
Broward Point Turn (West) - Drummond Creek Range (North)	0.19	0.039	-19.1	-10.7	-46.9	-90.9
Drummond Creek Range	0.14	0.005	-8.2	-20	-32.5	-40.0
Trout River Cut Range (North)	0.15	0.025	0.3	31.0	-42.2	-88.0
Trout River Cut Range - Chaseville Turn	0.10	0.005	-4.0	128.1	-48.0	-53.2
Long Branch Range	0.04	0.001	-0.7	0.0	-3.4	0.0
Terminal Channel	0.04	0.001	-31.9	0.0	-13.5	0.0
Total Average	0.17	0.021	-2.3	9.4	-9.3	-13.2

Table 5
Simulated Erosion in Four Specific Sites within the St. Johns River

	Erosion, Existing Conditions, ft		Erosion Rate Change, Plan A, percent		Erosion Rate Change, Plan B, percent	
Location	Fine Sand	Medium Sand	Fine Sand	Medium Sand	Fine Sand	Medium Sand
St. Johns Bar Cut Range, West Section, (Northern Coastline)	-1.70	-0.057	-37.5	-21.5	-34.3	-17.1
Training Wall Reach (Northeastern Coastline)	-1.78	-0.062	-0.8	-9.2	4.2	-1.4
White Shells Cut Range (Southwestern Coastline)	-1.18	-0.040	13.3	16.7	20.6	21.0
Quarantine Island Upper Range (Northern Coastline)	-1.53	-0.050	1.0	-6.7	-2.7	5.3
Total Average	-1.60	-0.054	-11.8	-10.5	-10.12	-2.8

Conclusions

The numerical simulation of hydrodynamics and sedimentation in the Lower St. Johns River indicates that the three channel plans differ in their impacts upon the river navigation. Plan B decreased the water current velocities at three locations of the navigation channel by more than 5 percent. The Terminal Channel, a straight portion of the river, was the only place where Plan B resulted in increased velocities; Plans A and C with Mill Cove 5 also increased velocities in this part of the channel. Plan A decreased velocities at one location, while Plan C with Mill Cove 5 showed mixed results by decreasing velocities in three places and increasing velocities in five.

The numerical sediment transport model in the navigation channel resulted in the following: Plan B reduced the total fine and medium sediment deposition rates throughout the navigation channel, and Plan A produced a negligible decrease in the total fine sand deposition across the navigation channel while increasing medium sand deposition.

When considering the sites as a group, Plan A reduced the total sediment erosion at four specific places of the river coastline more than Plan B. Both plans considerably reduced erosion at the northern coastline of the St. Johns Bar Cut Range and increased erosion at the southwestern coastline of the White Shells Cut Range. The proposed plans did not greatly affect the erosion rates at the other two sites.

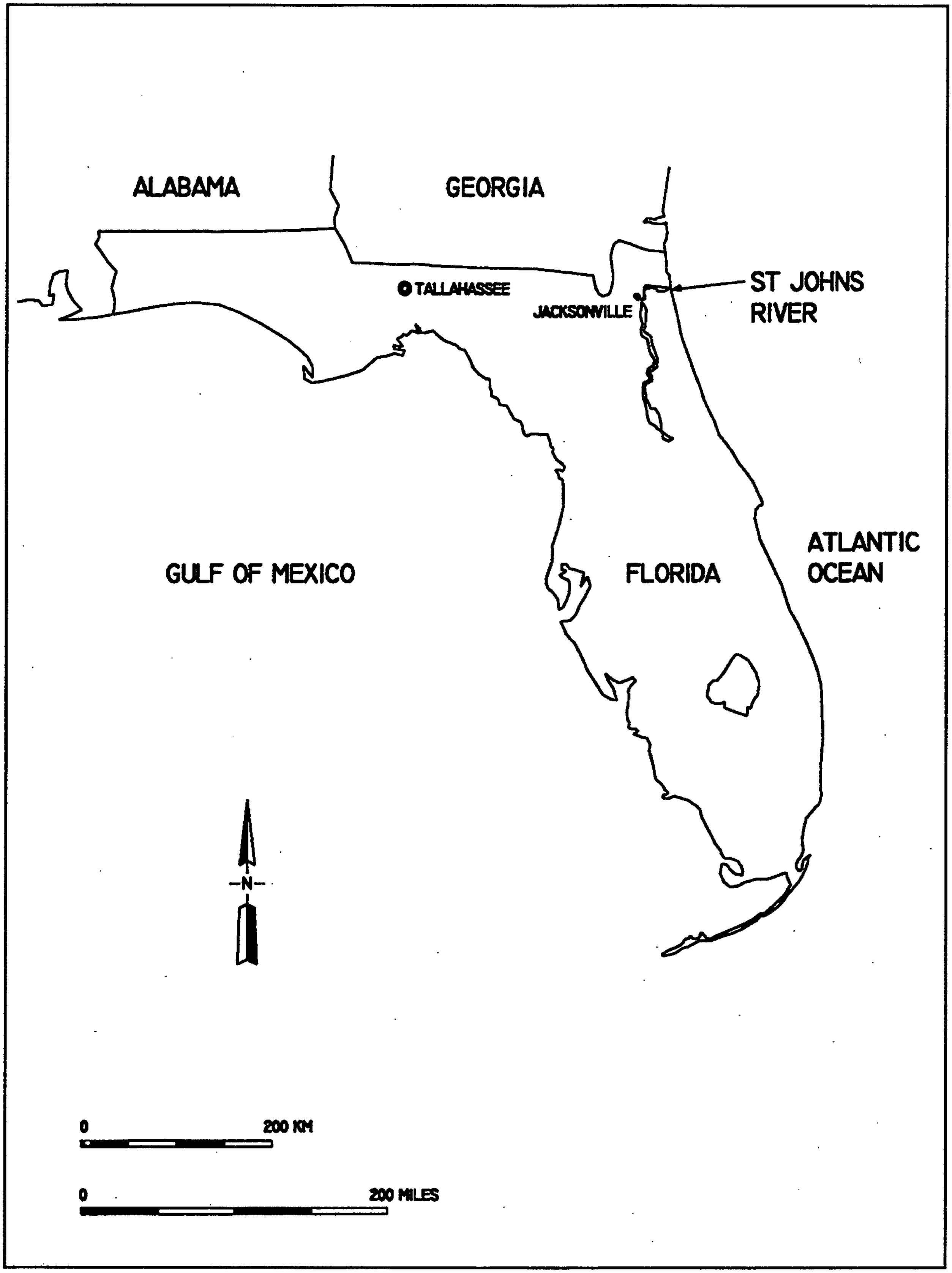

Figure A1. Location map

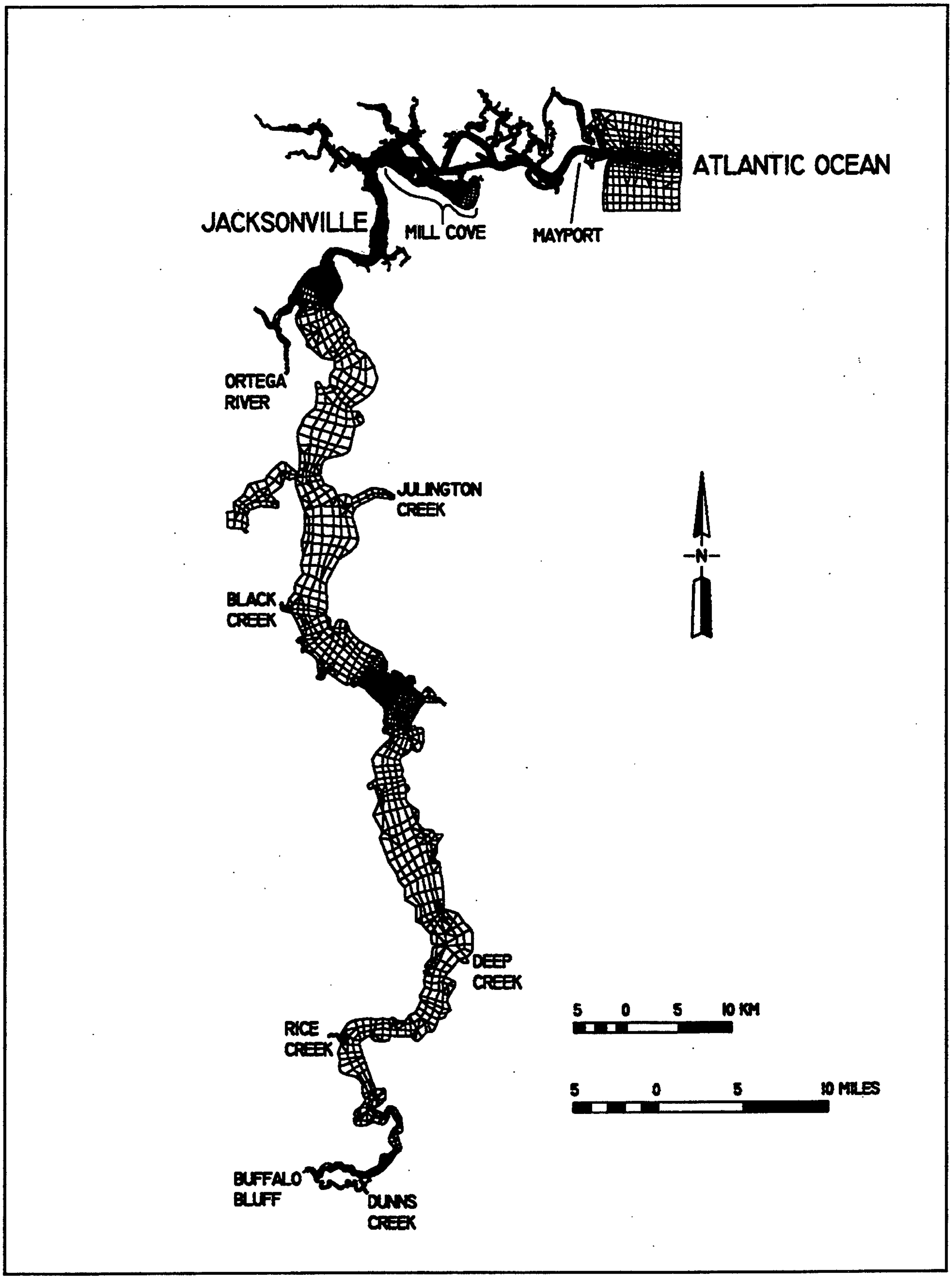

Figure A2. Numerical mesh for the lower St. Johns River

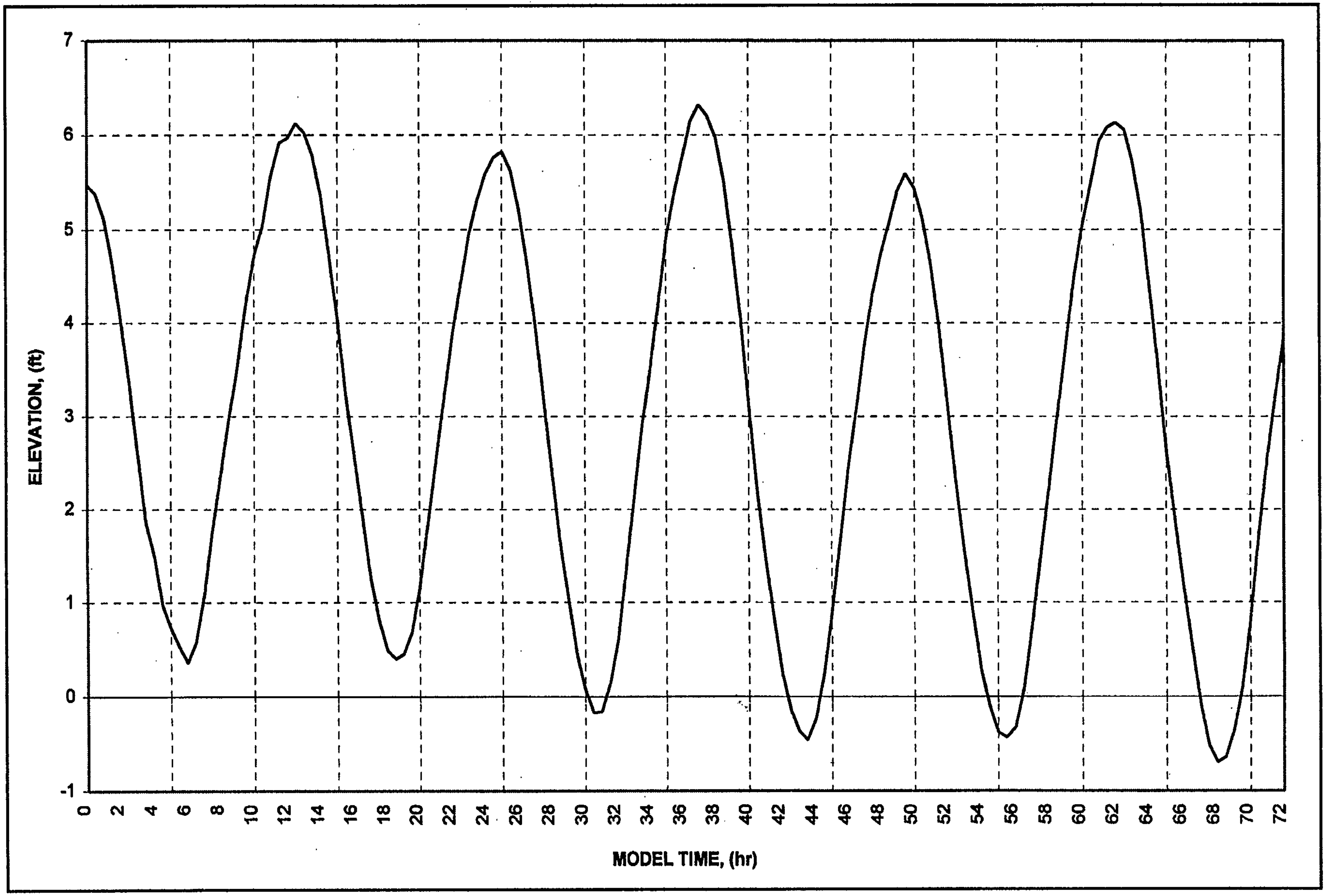

Figure A3. Water surface elevation at boundary (offshore)

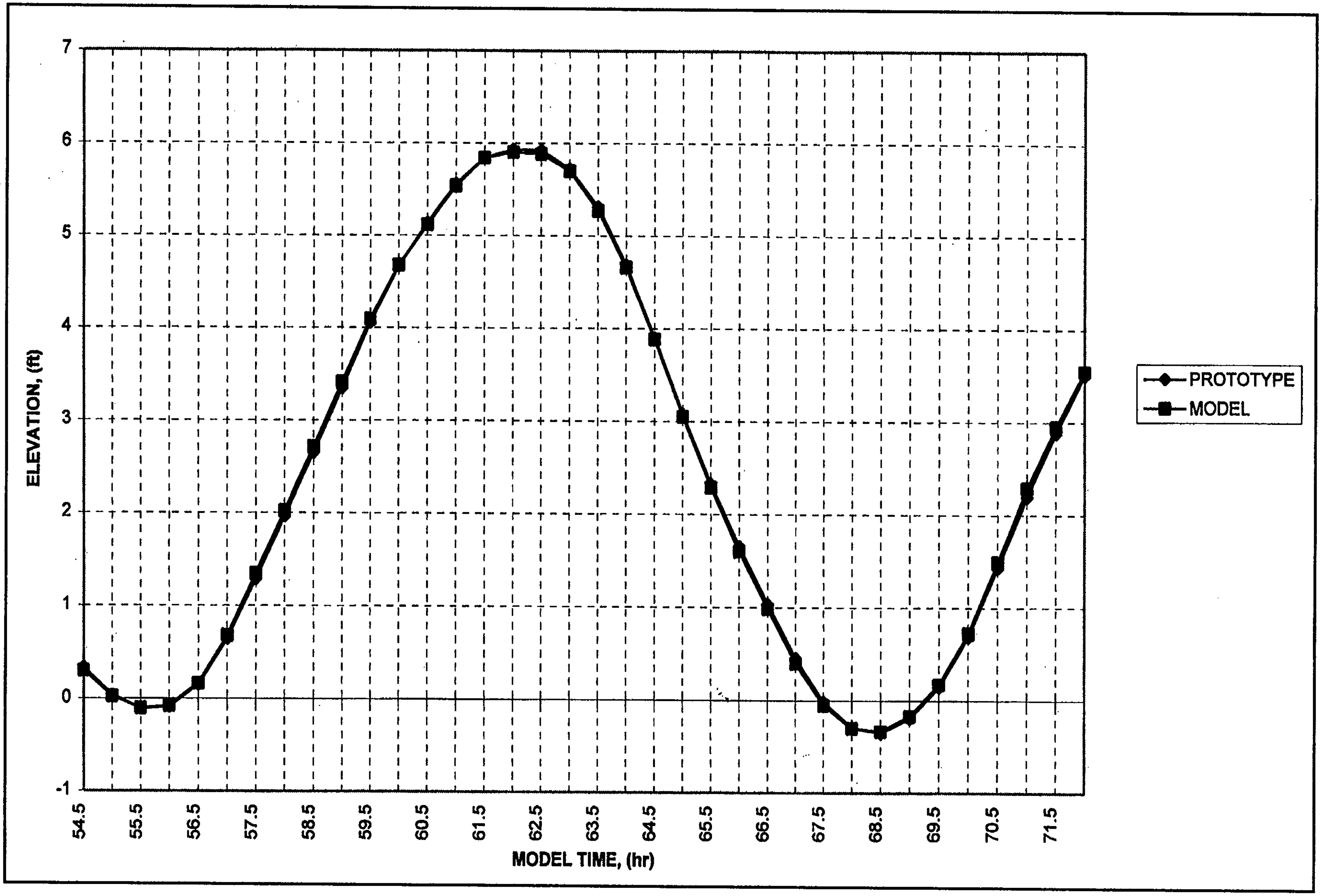

Figure A4. Water surface elevation at Mayport

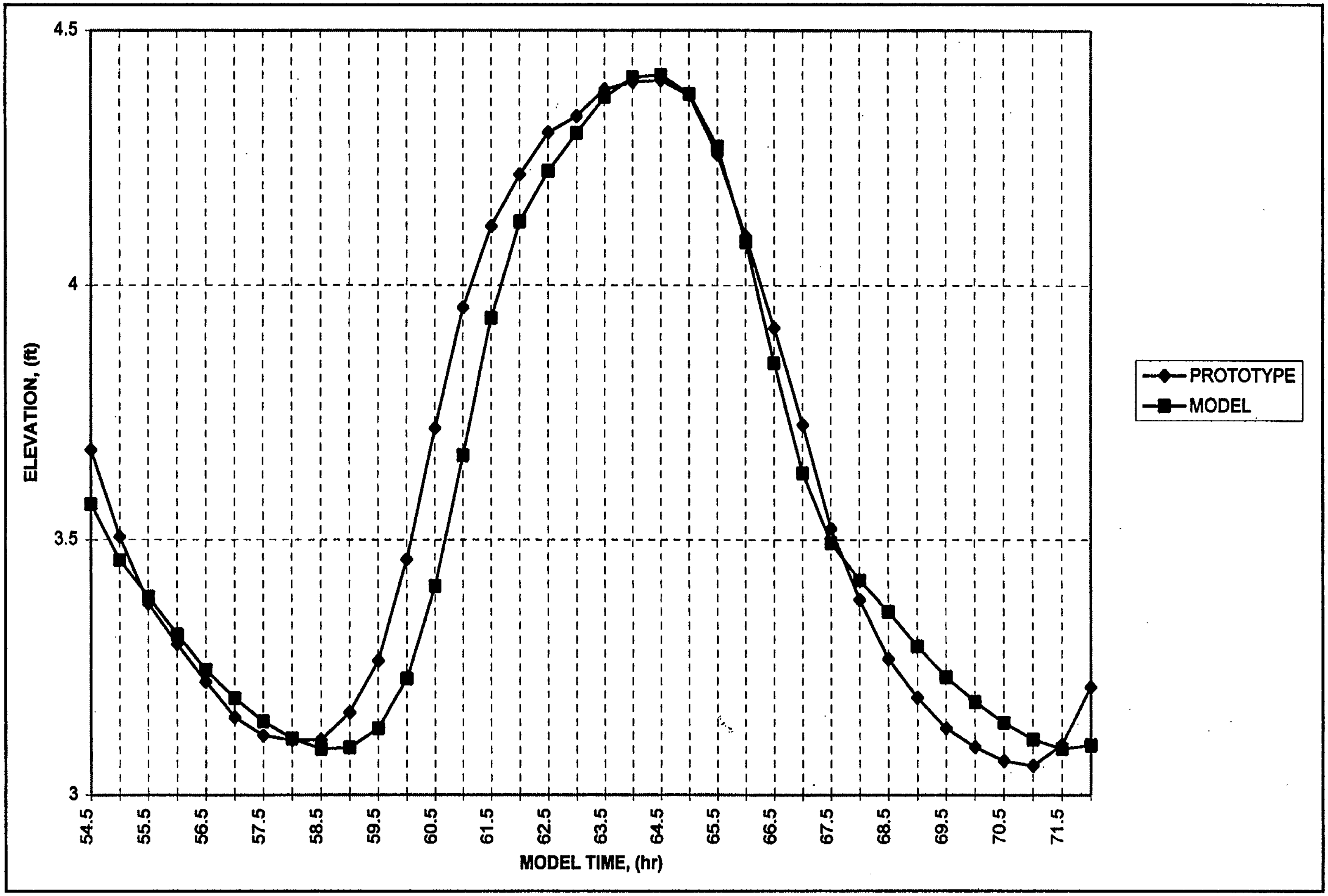

Figure A5. Water surface elevation at South Jacksonville

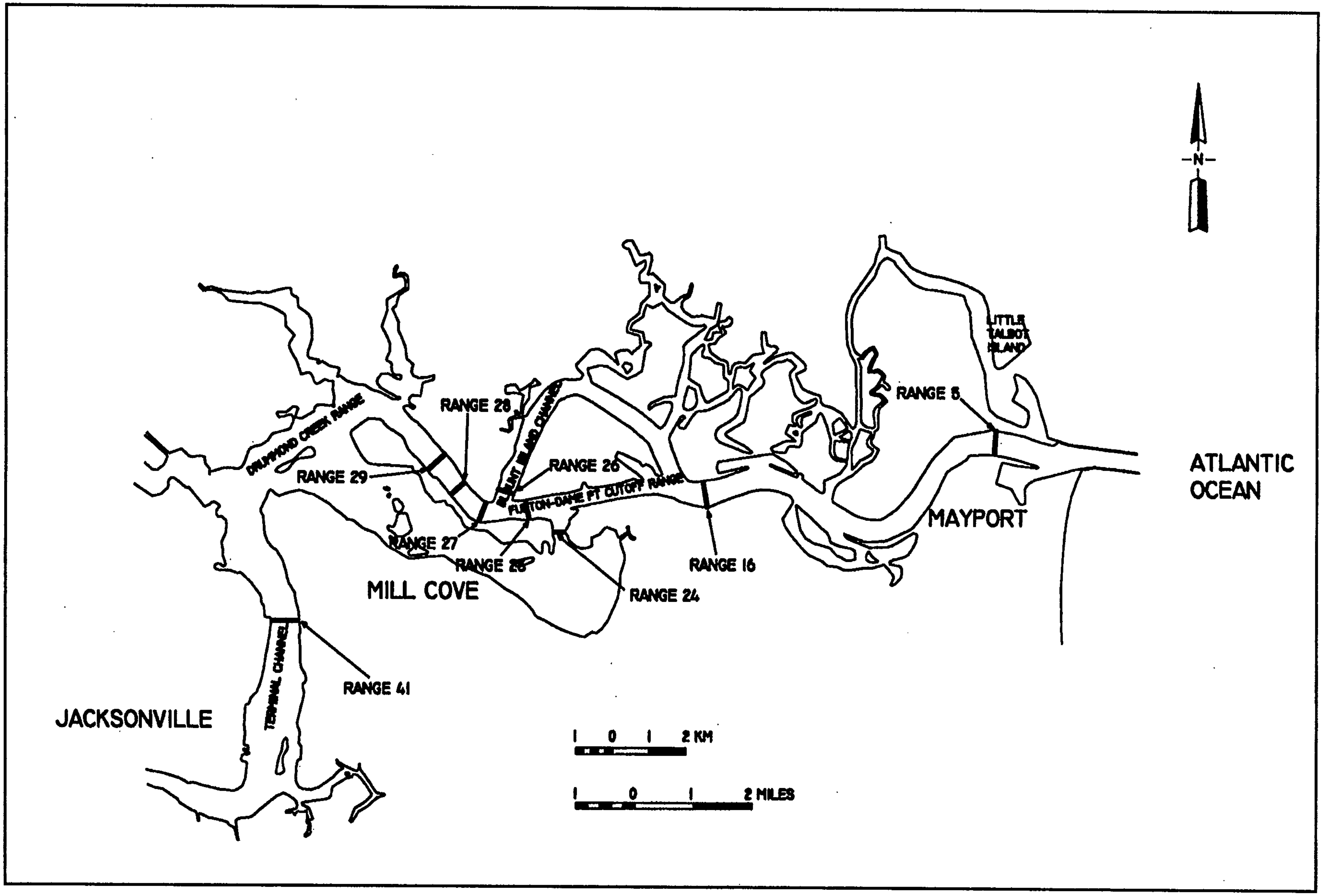

Figure A6. Location of ranges used for model verification

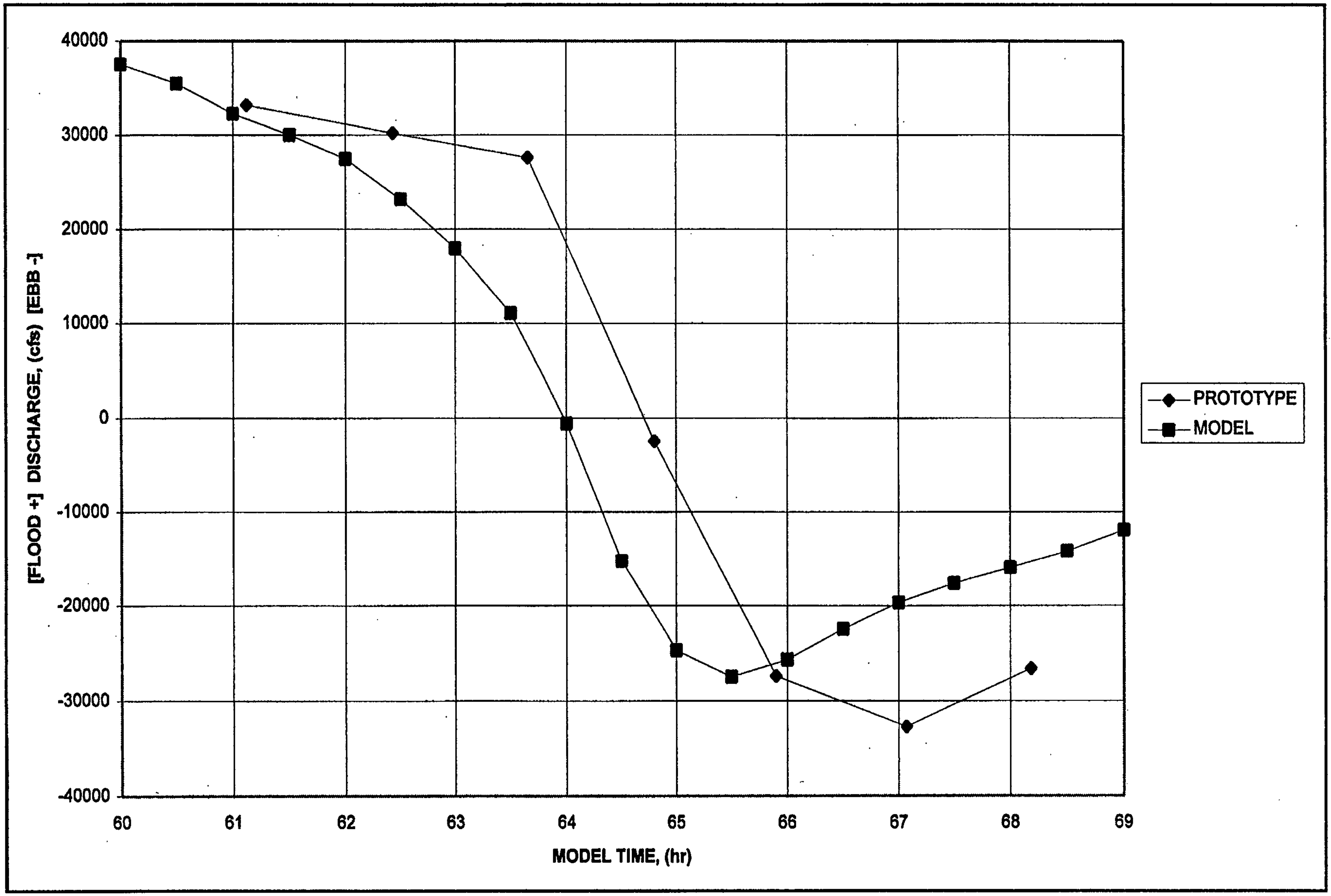

Figure A7. Water discharge at Range 24

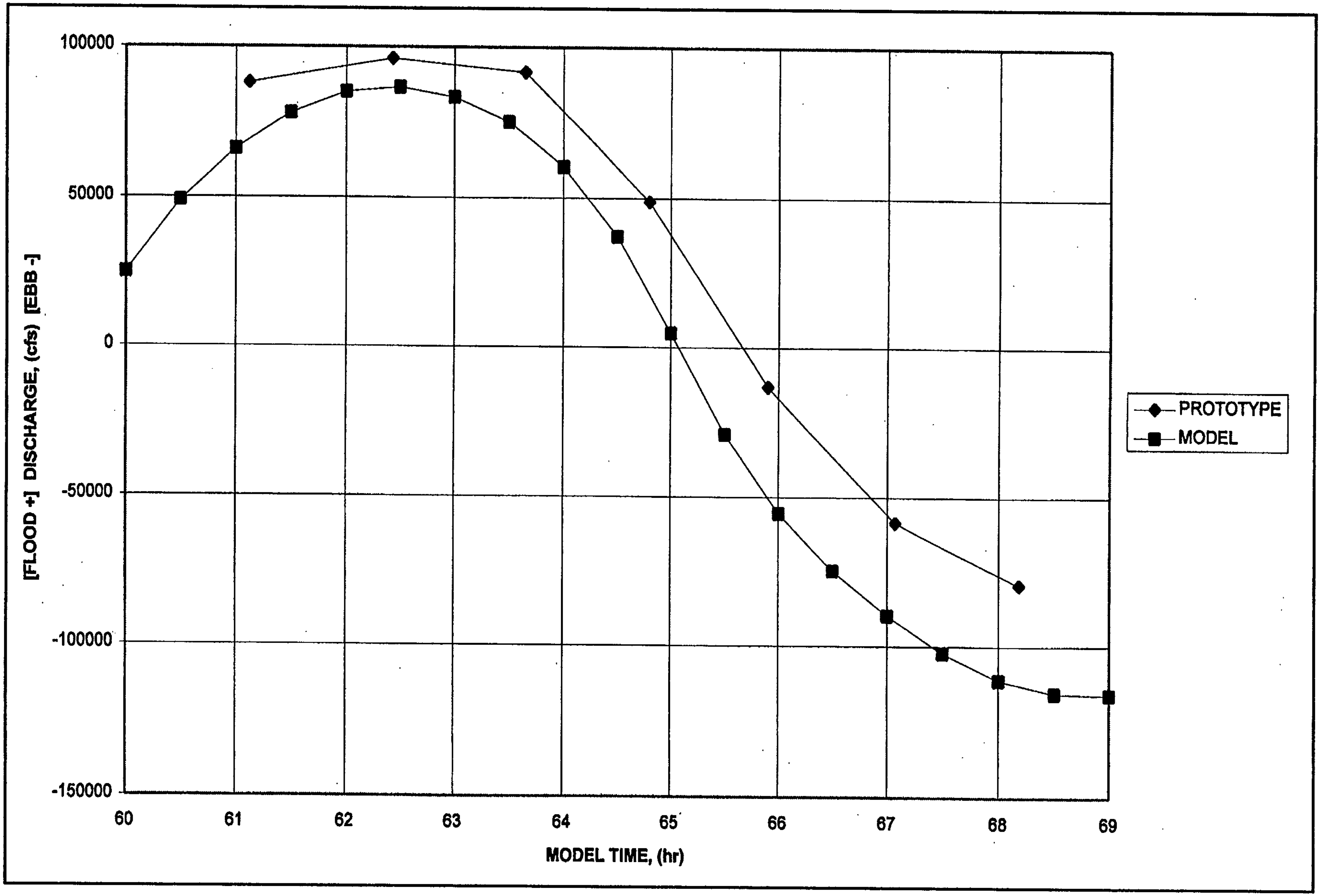

Figure A8. Water discharge at Range 25

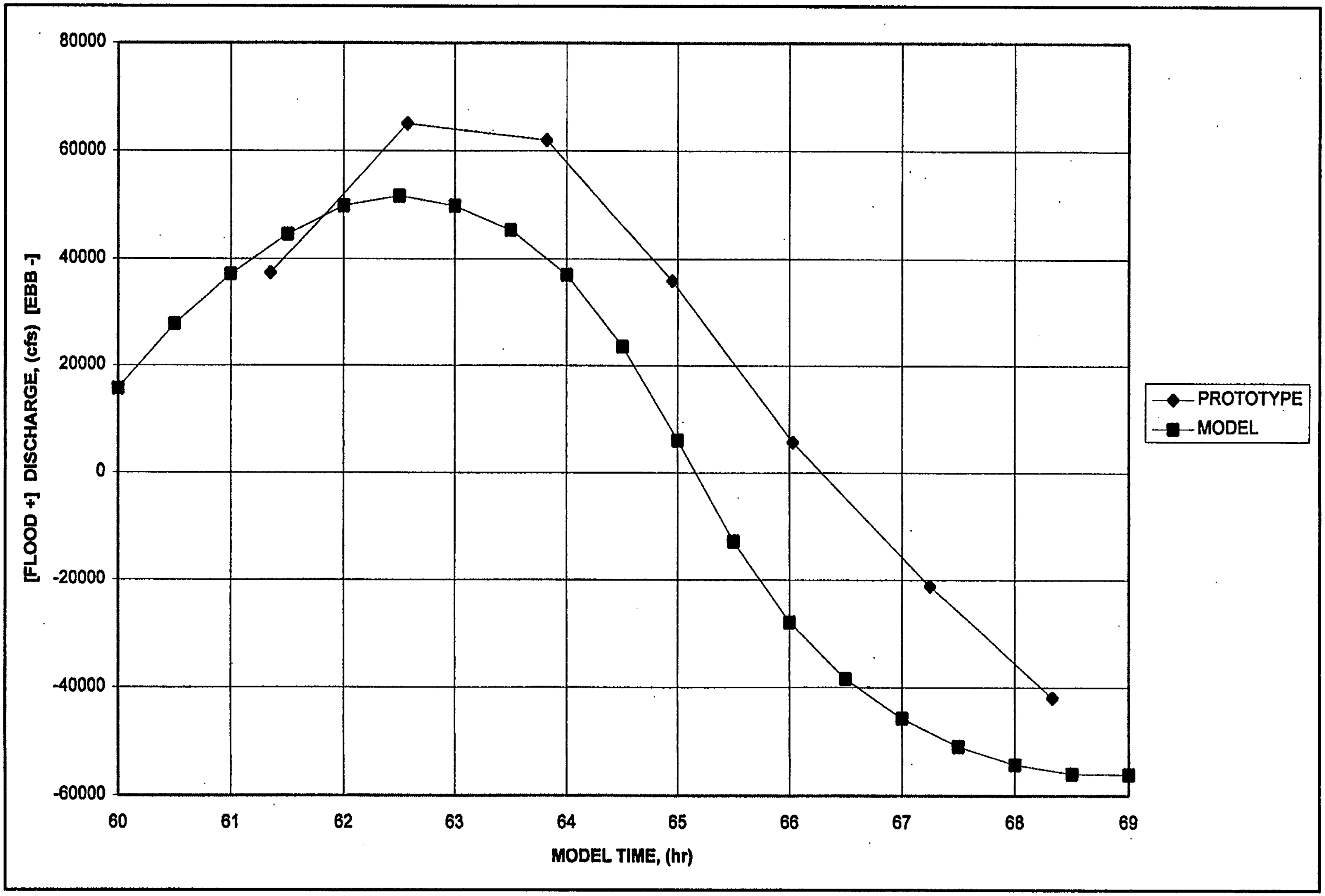

Figure A9. Water discharge at Range 26

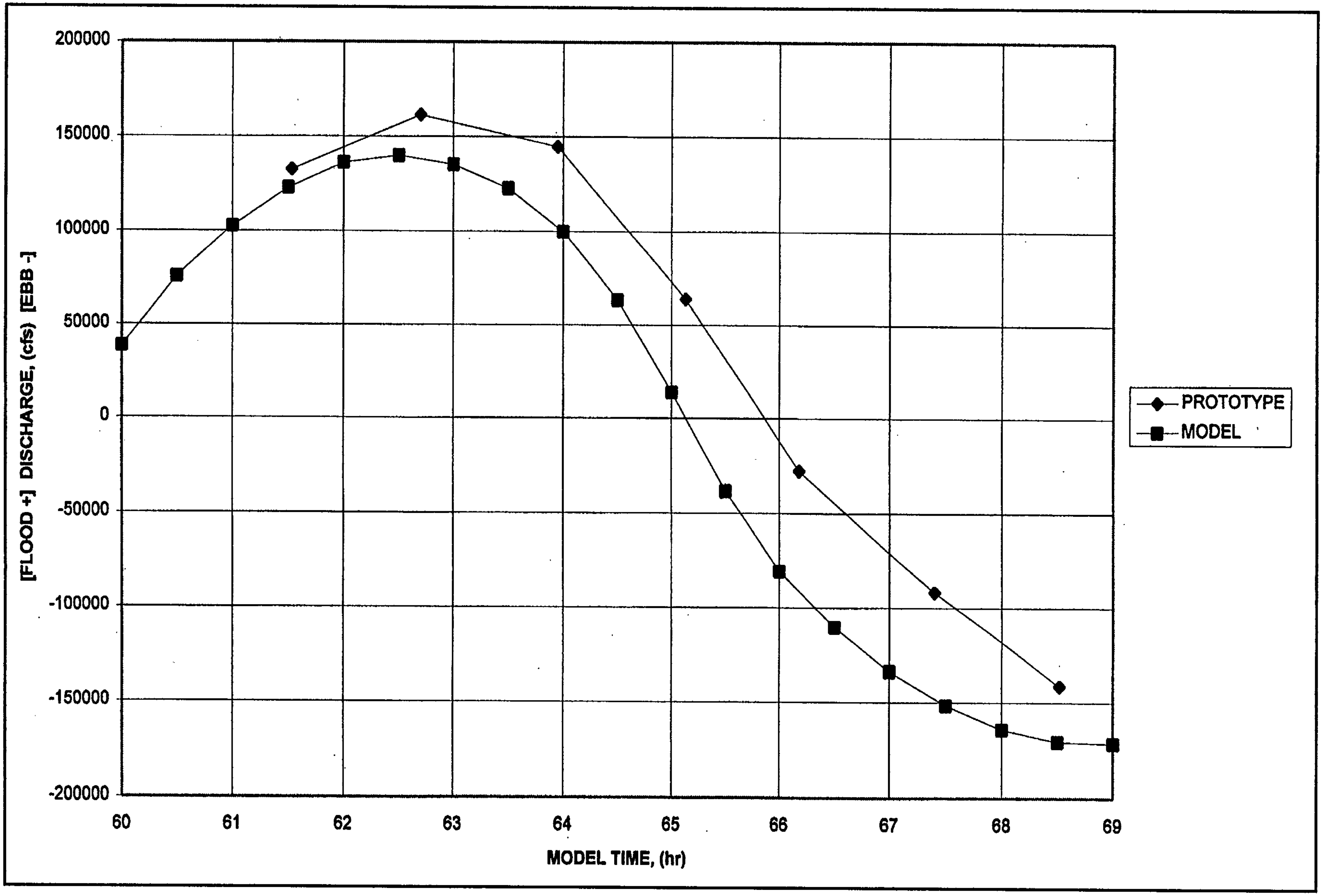

Figure A10. Water discharge at Range 27

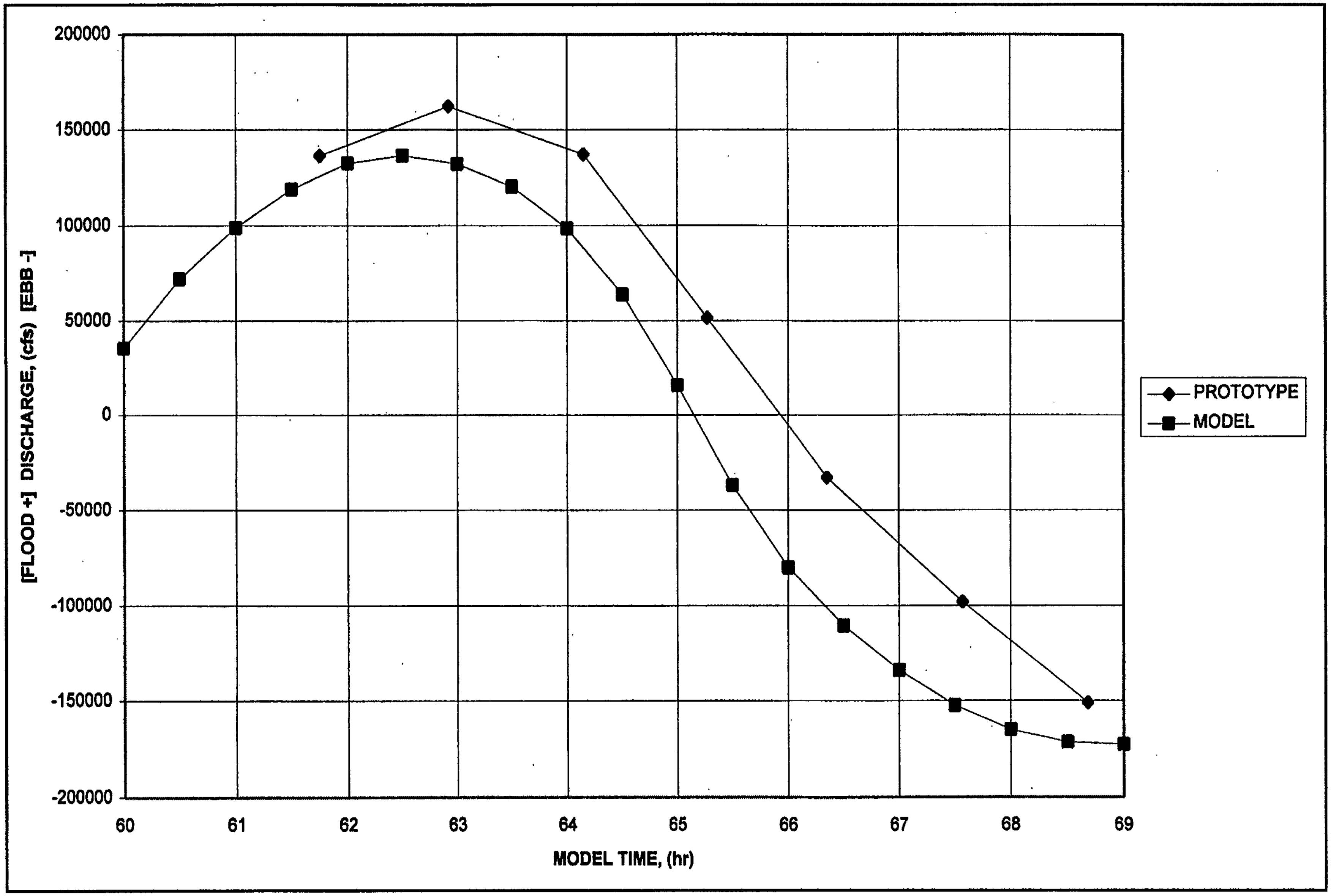

Figure A11. Water discharge at Range 28

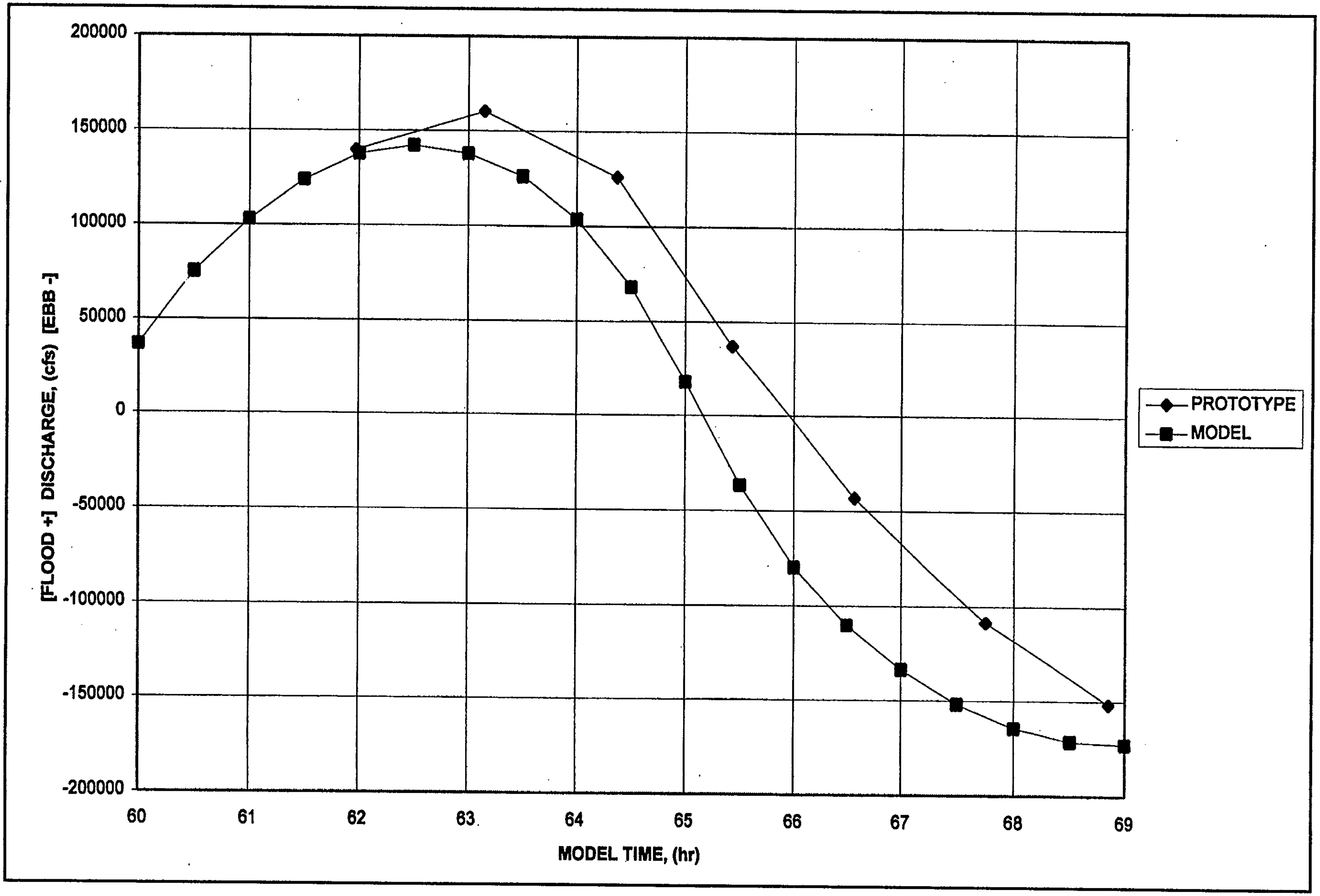

Figure A12. Water discharge at Range 29

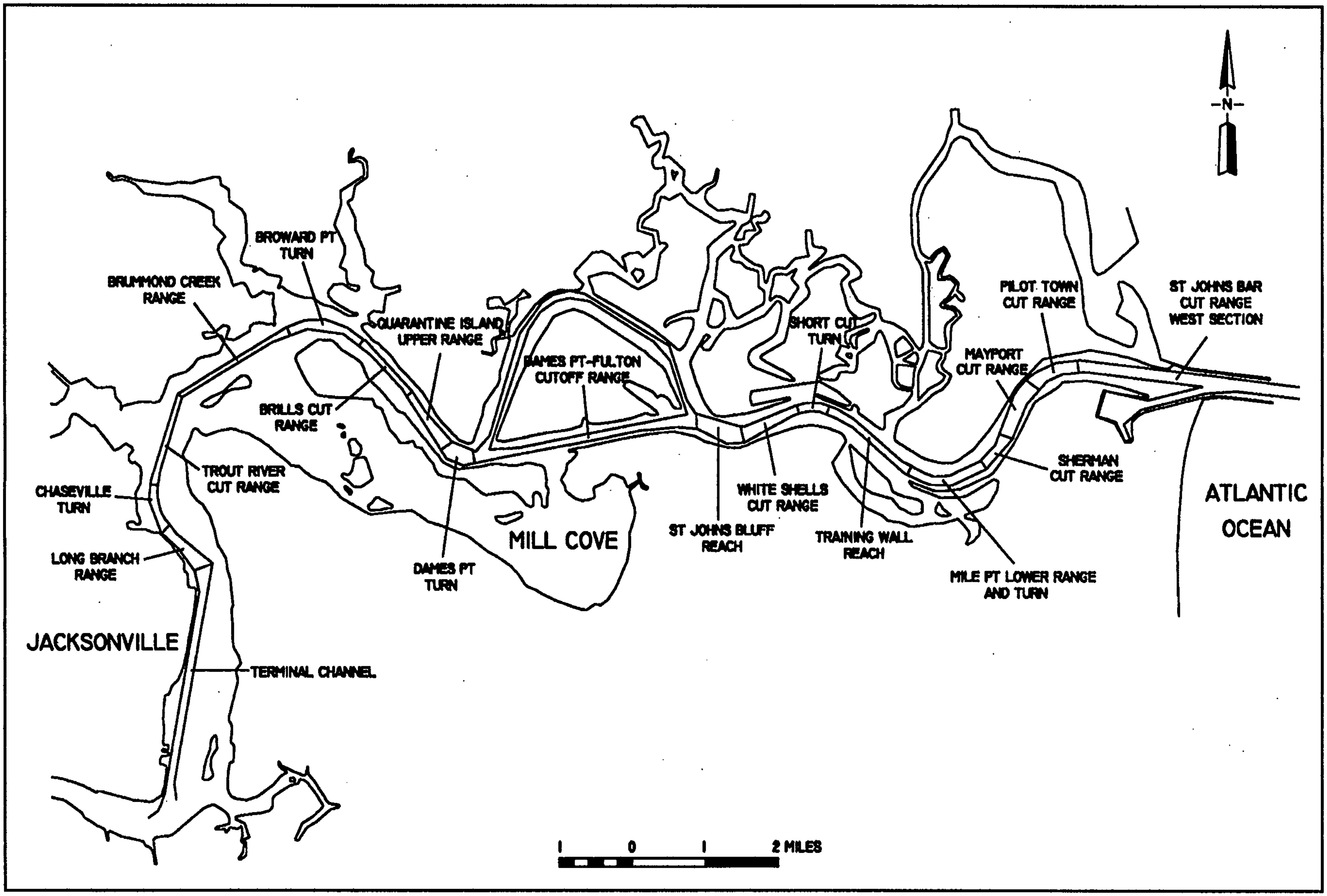

Figure A13. St. Johns River navigation channel

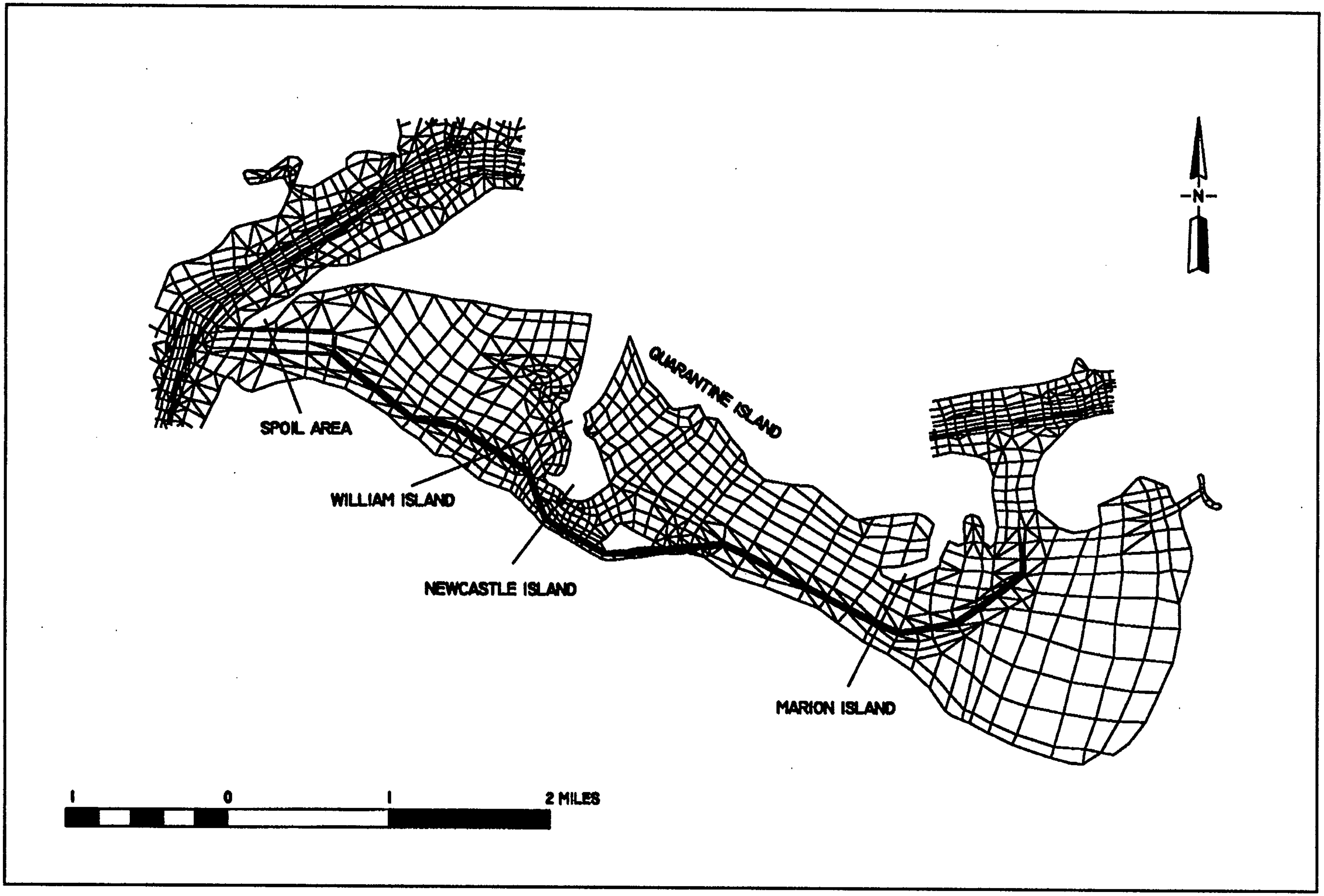

Figure A14. Numerical mesh at Mill Cove Plan 5

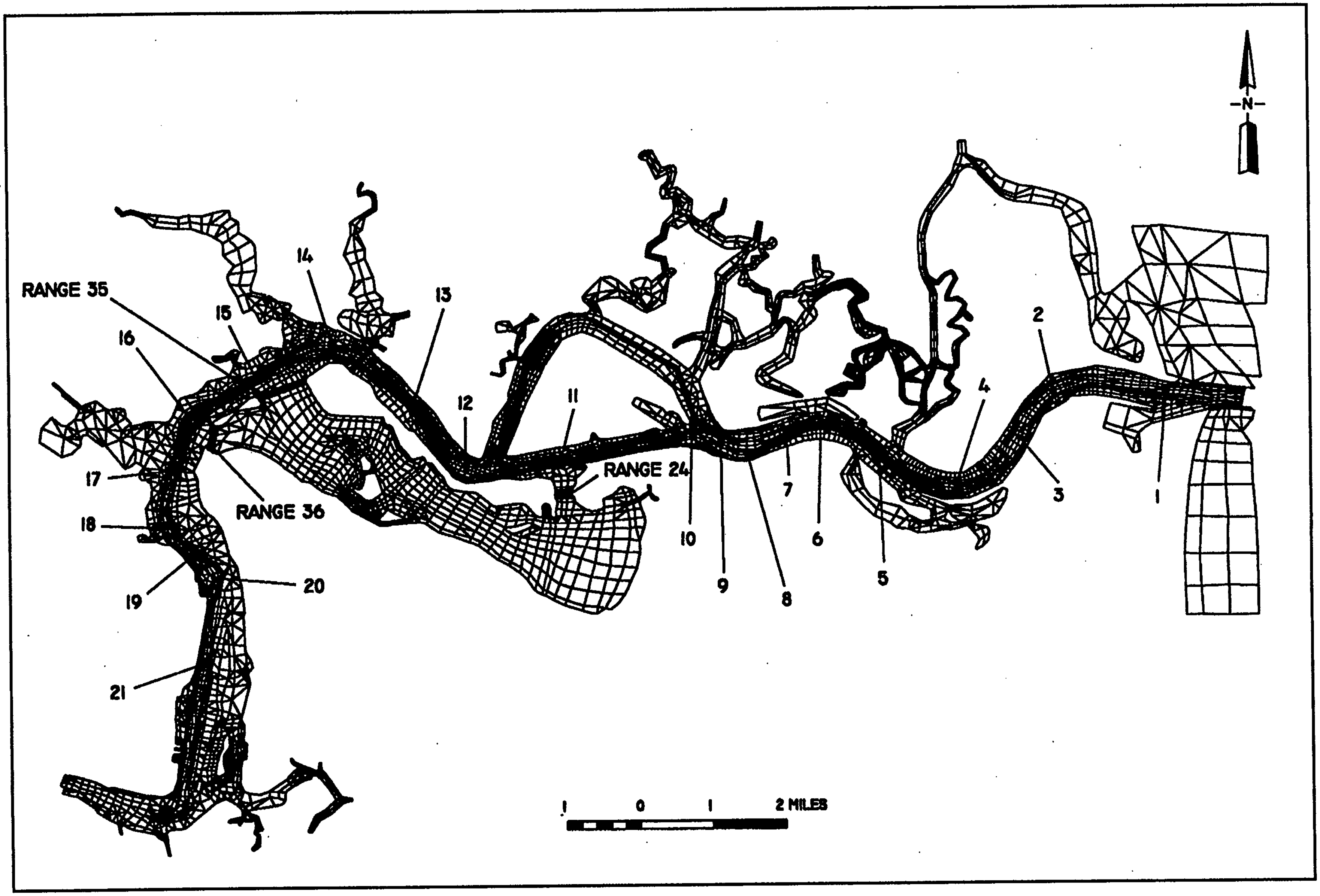

Figure A15. Location of stations and continuity check lines

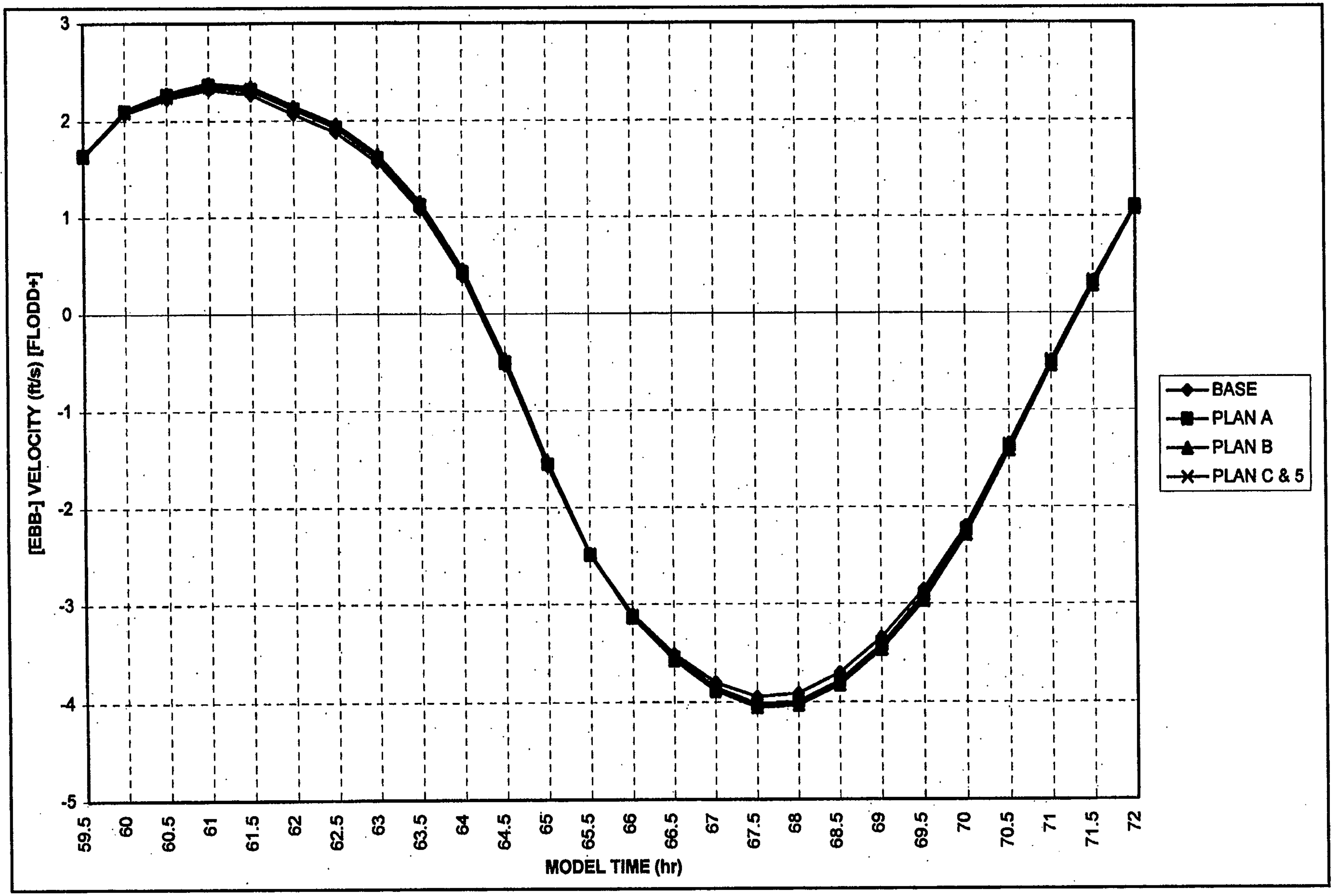

Figure A16. Velocity magnitude at node station 1

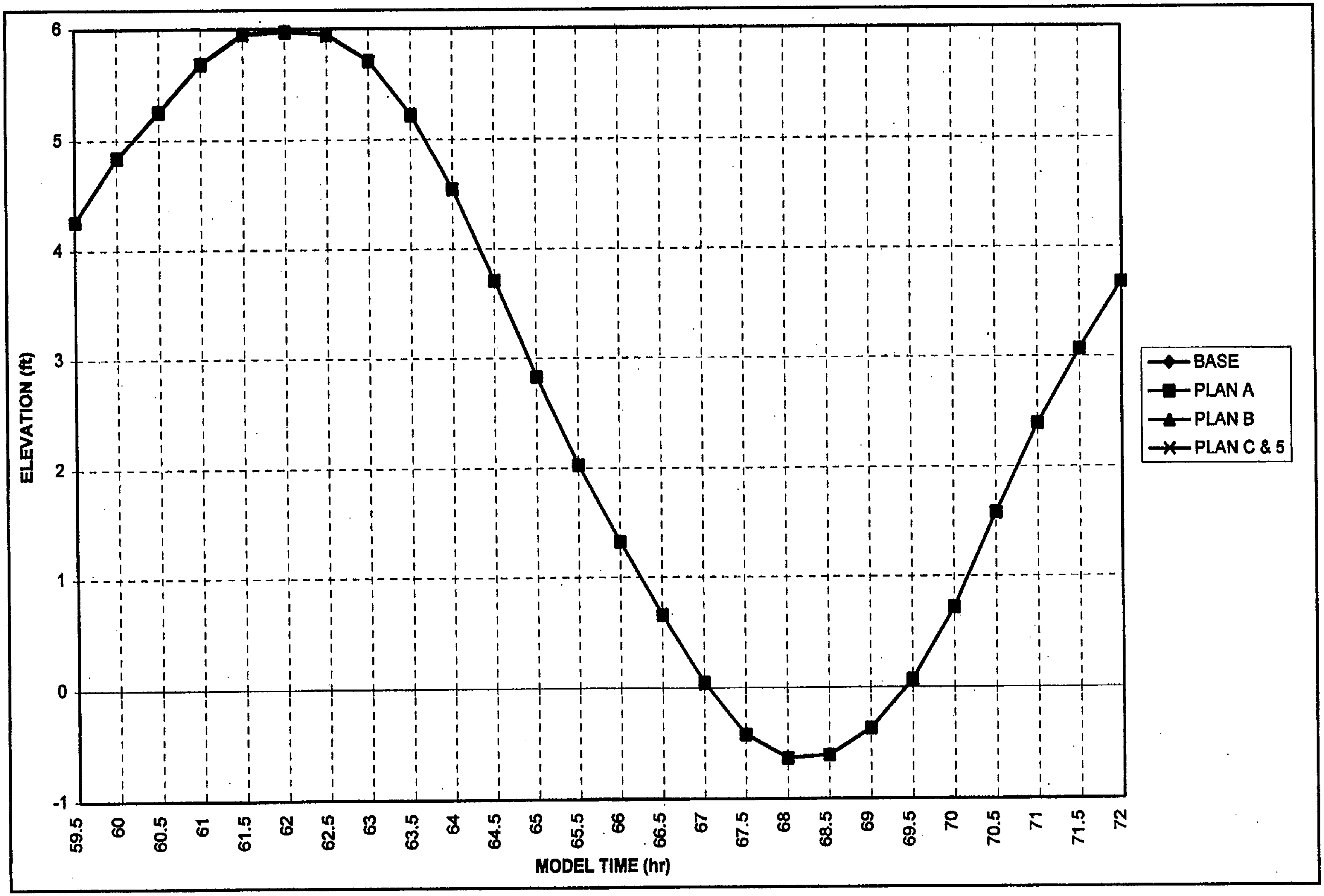

Figure A17. Water surface elevation at station 1

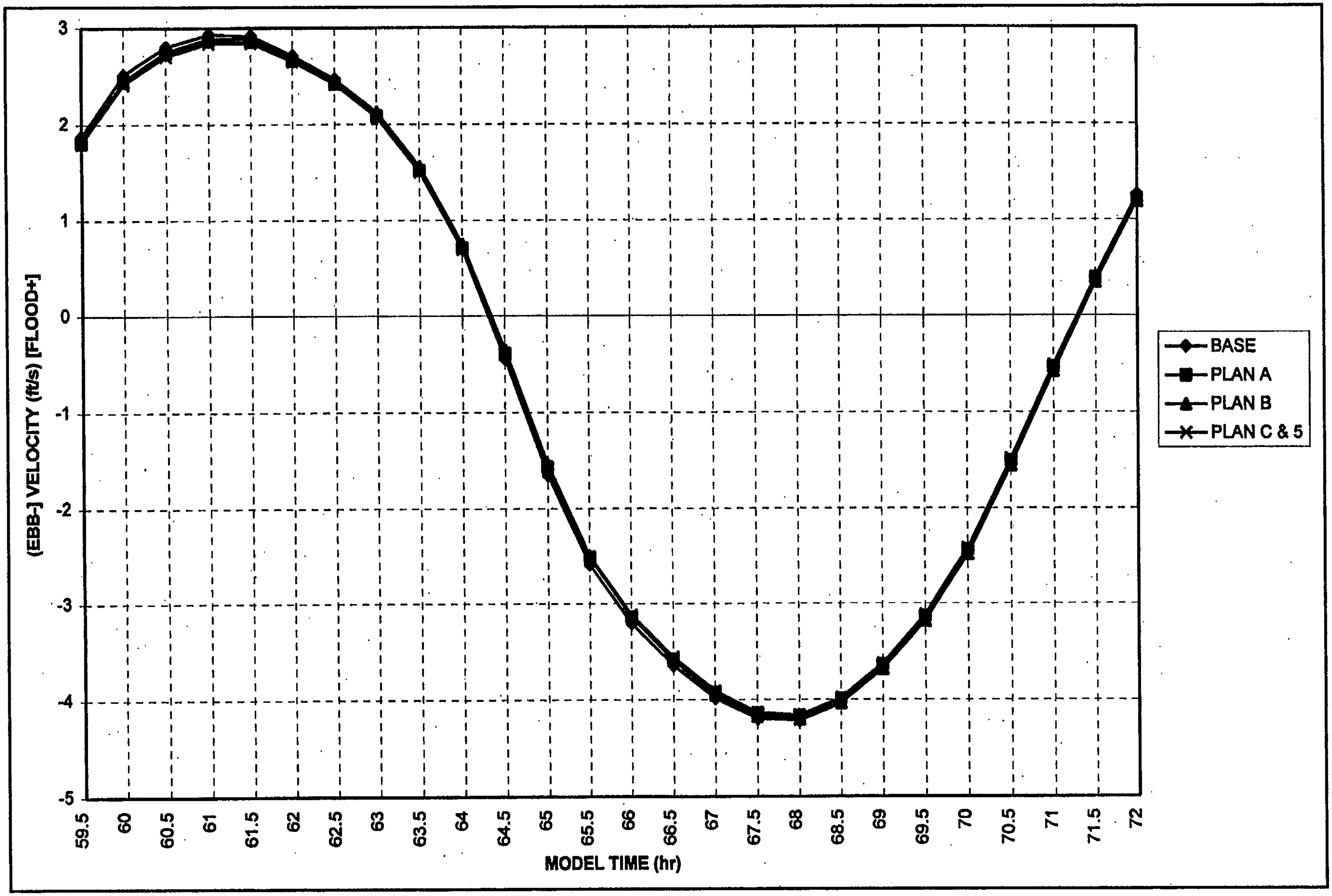

Figure A18. Velocity magnitude at station 2

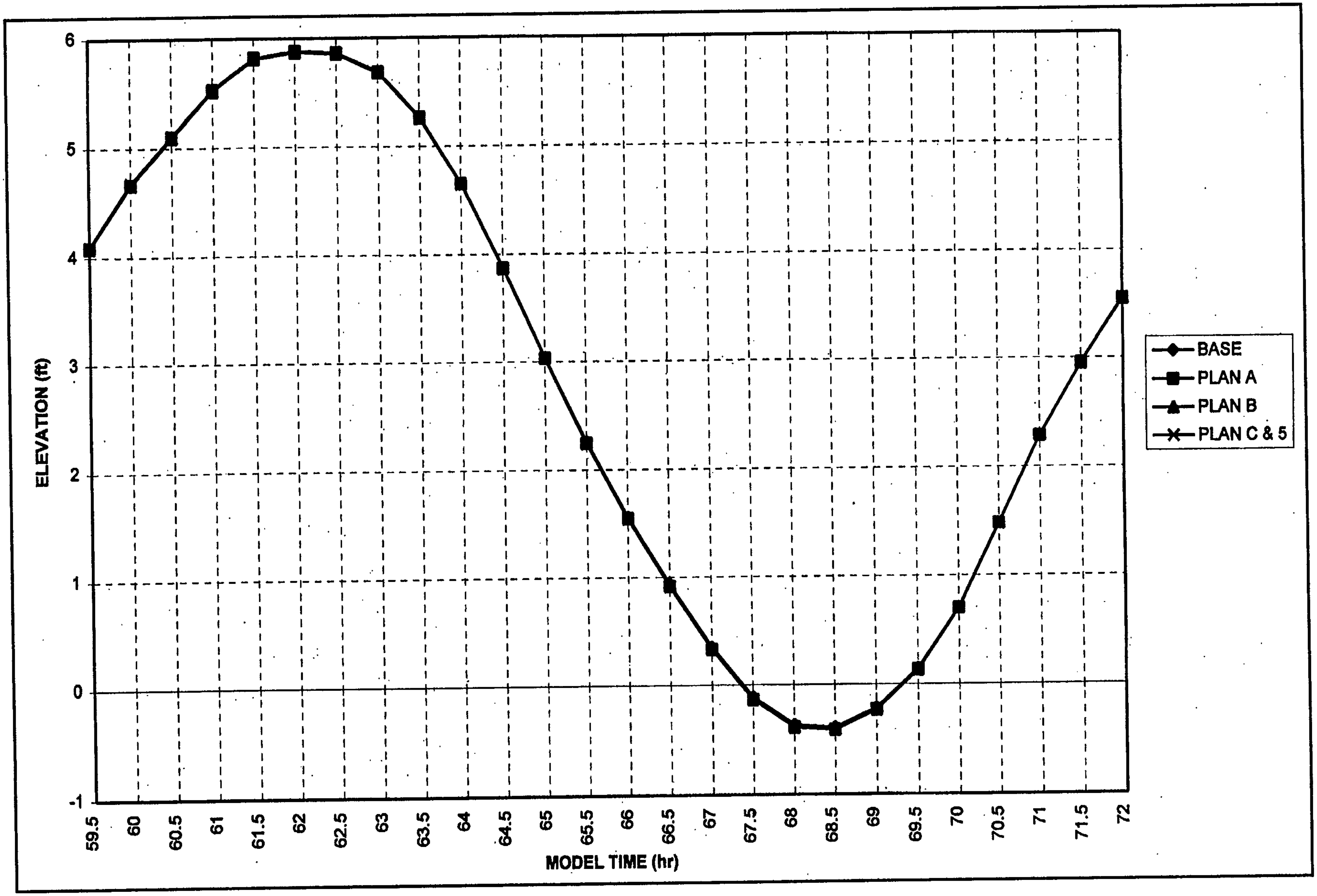

Figure A19. Water surface elevation at station 2

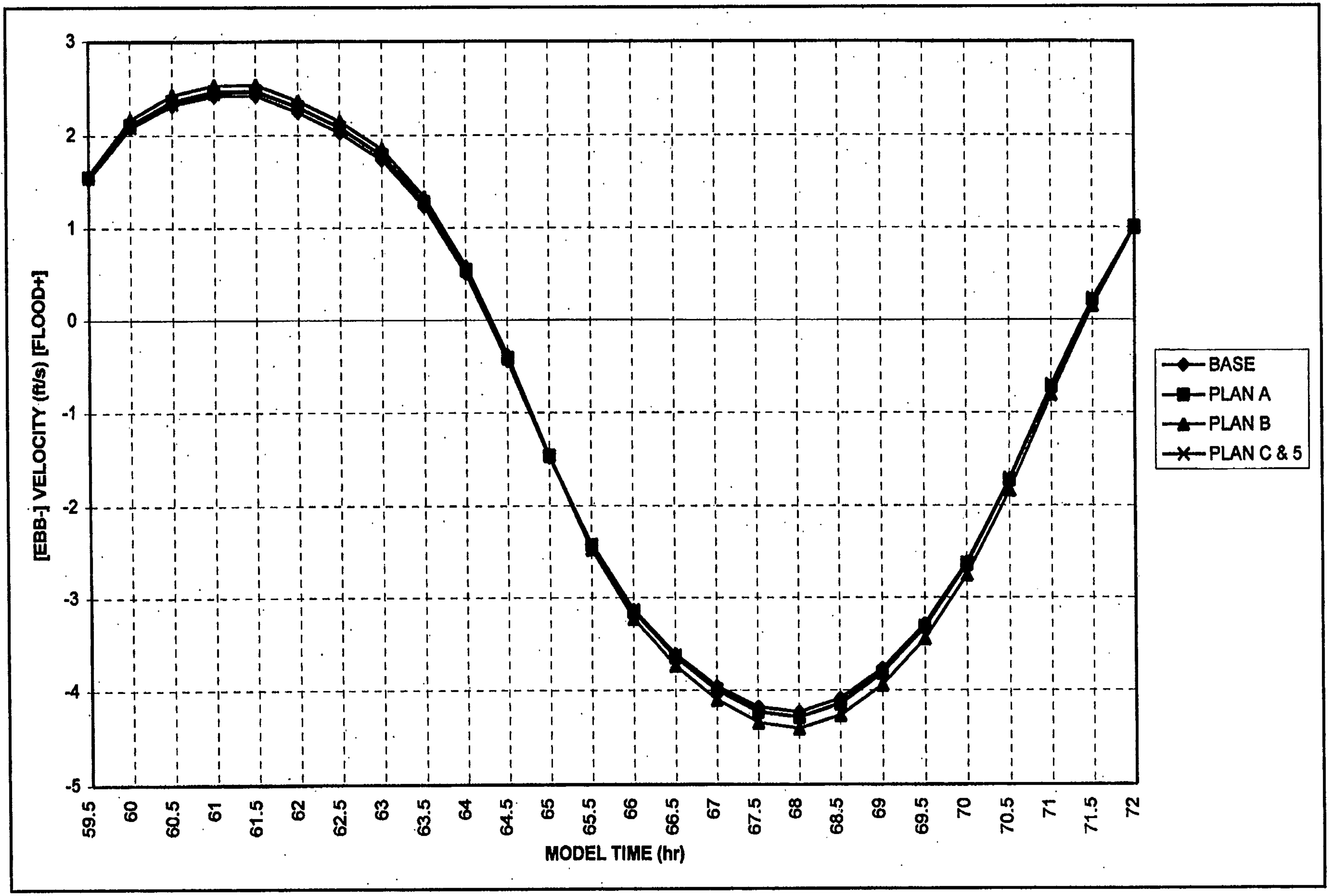

Figure A20. Velocity magnitude at node station 3

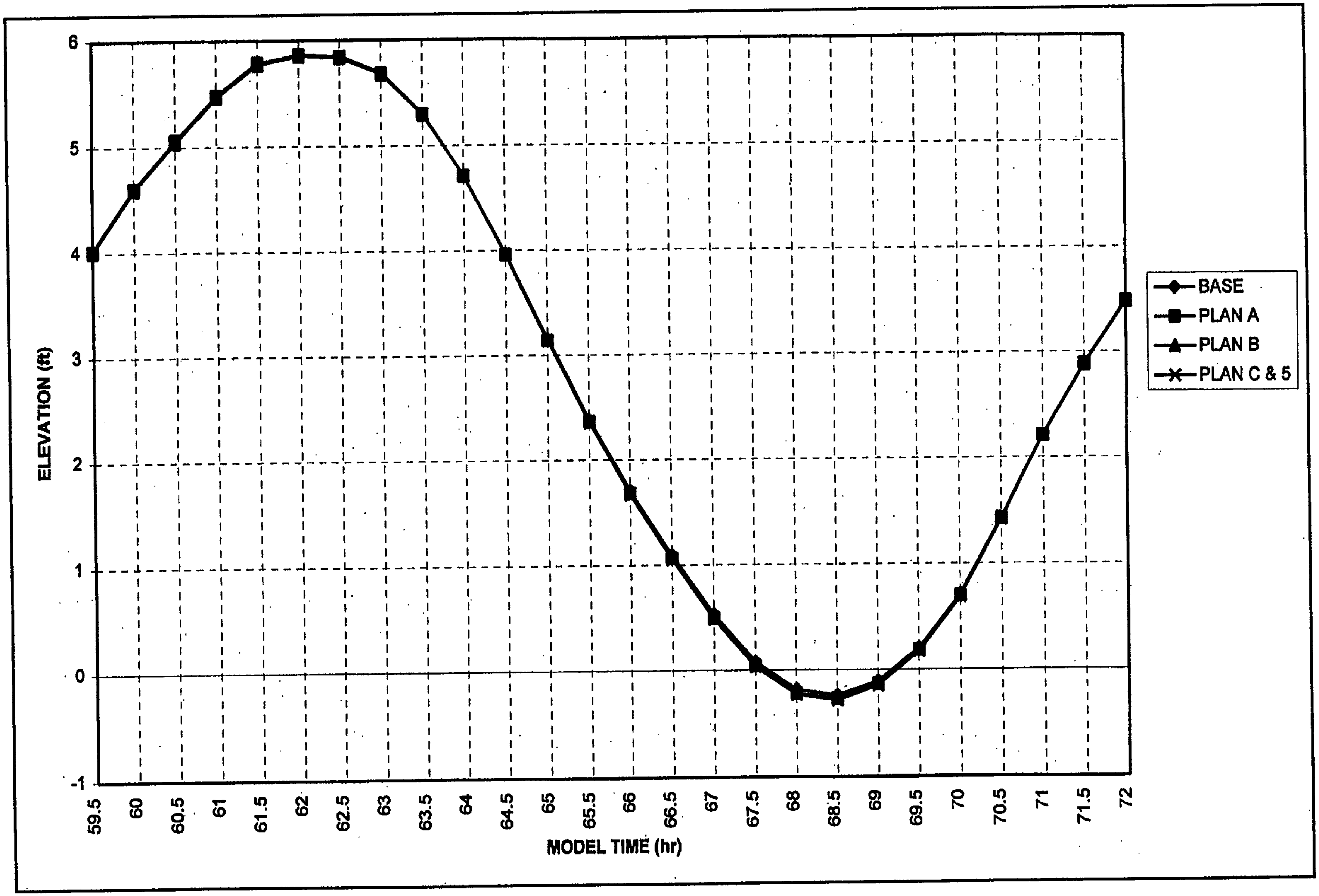

Figure A21. Water surface elevation at node station 3

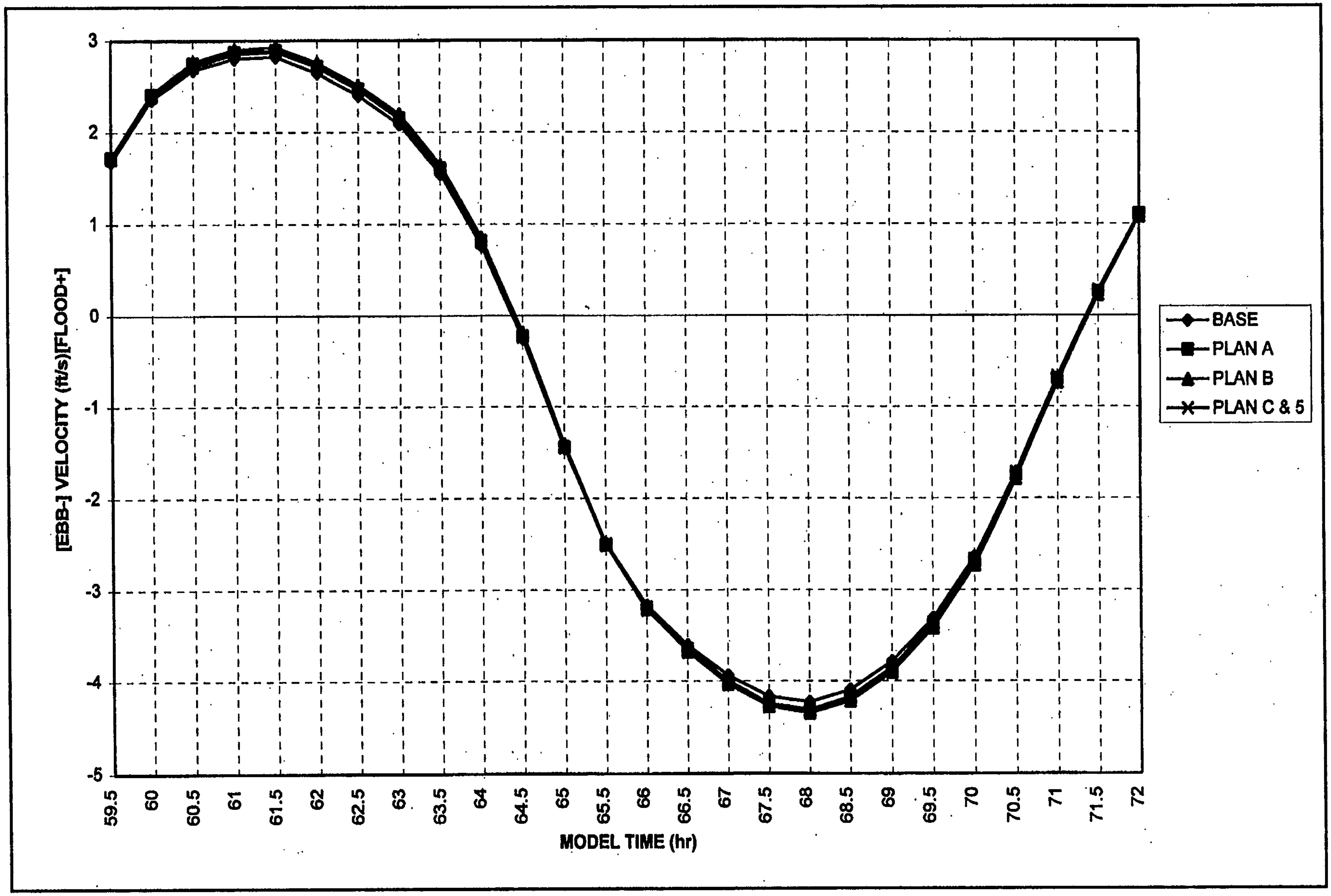

Figure A22. Velocity magnitude at station 4

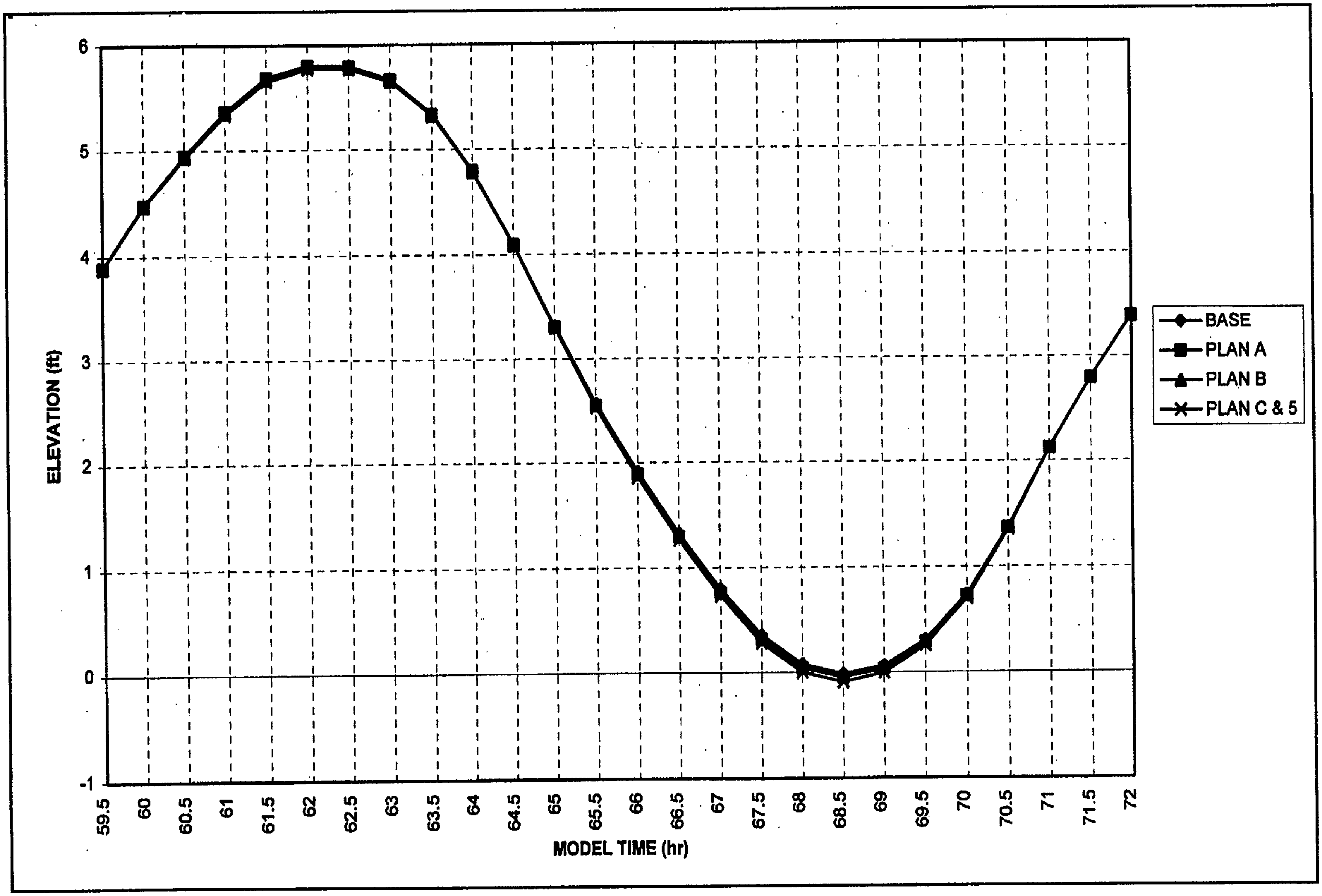

Figure A23. Water surface elevation at station 4

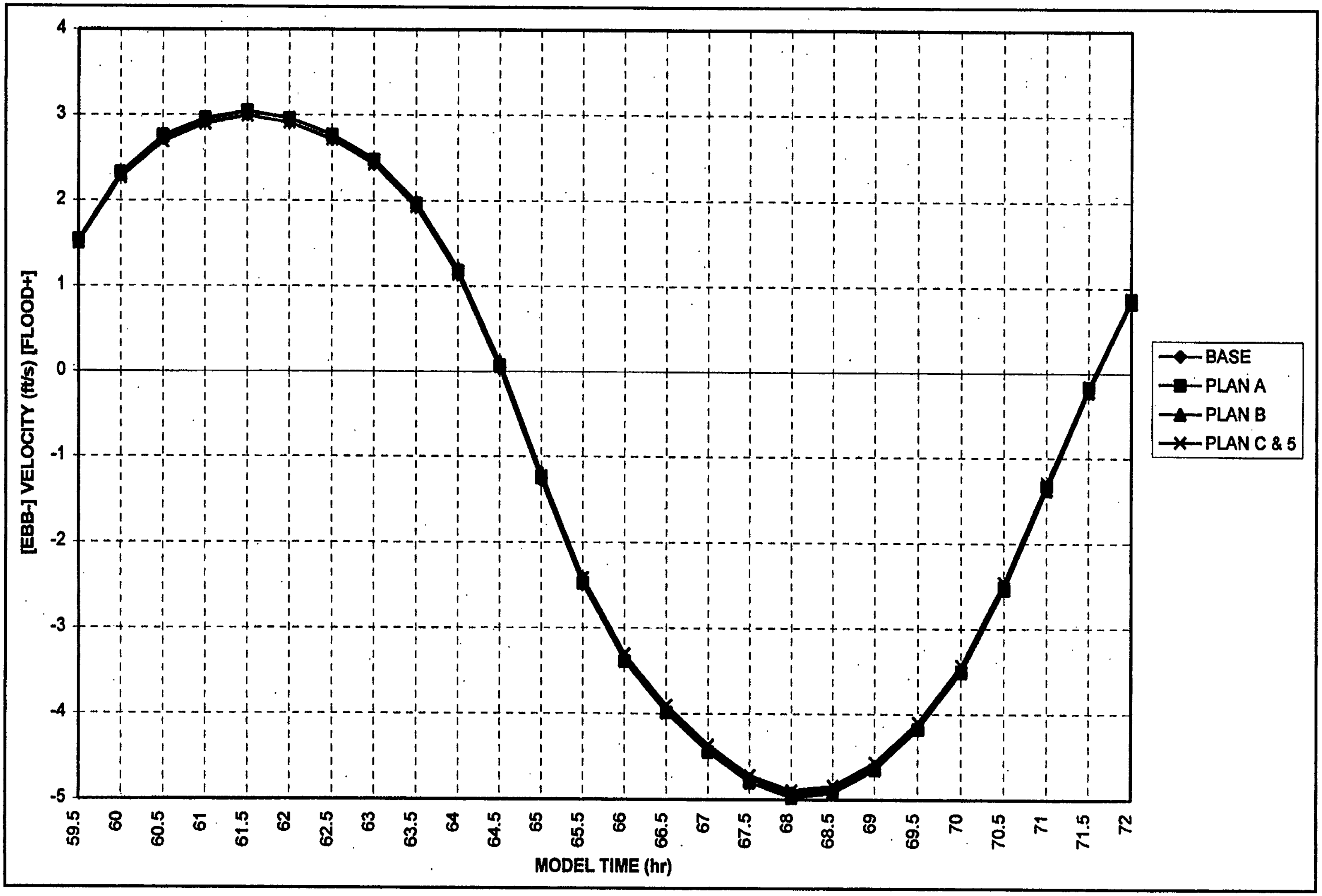

Figure A24. Velocity magnitude at station 5

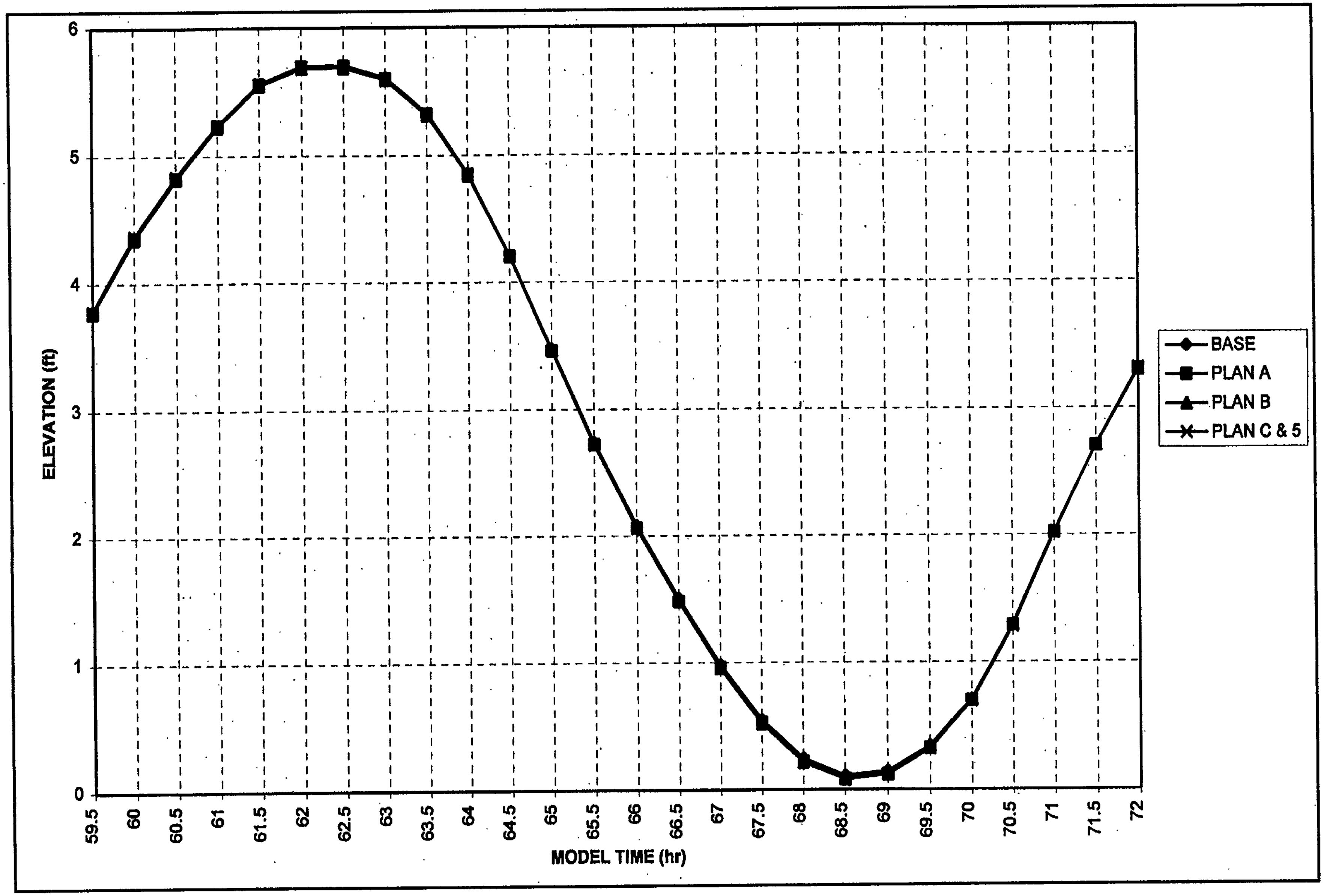

Figure A25. Water surface elevation at station 5

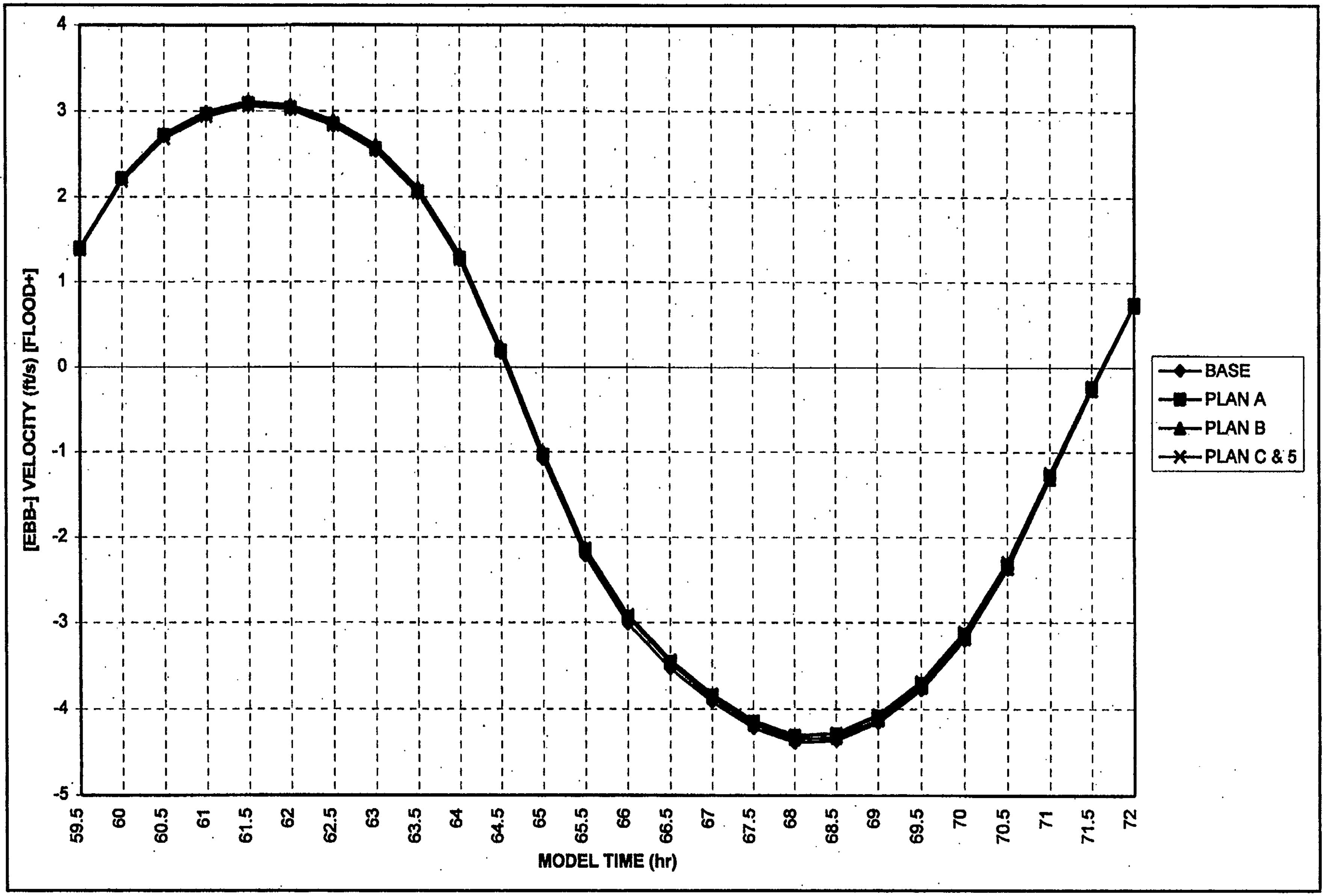

Figure A26. Velocity magnitude at station 6

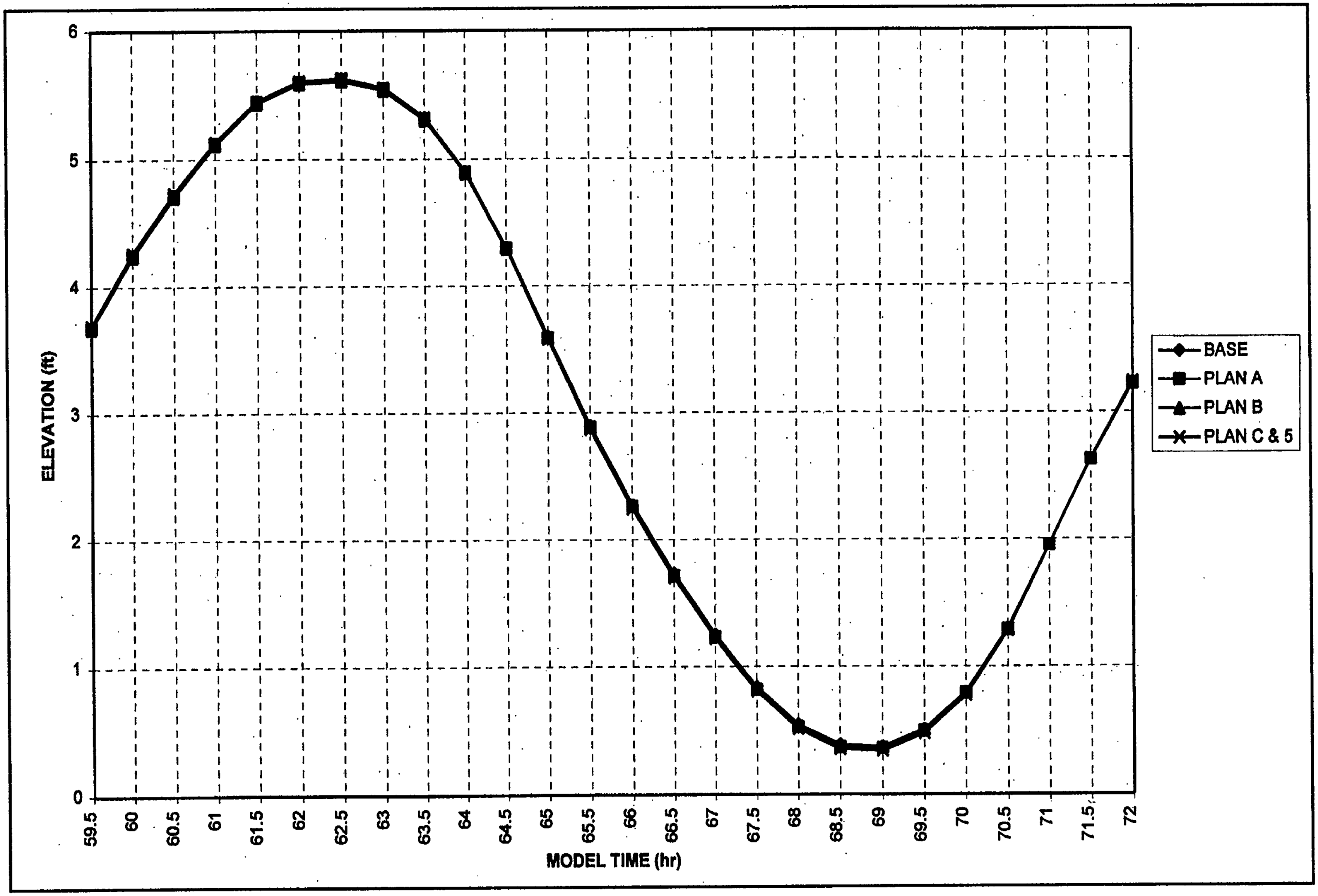

Figure A27. Water surface elevation at station 6

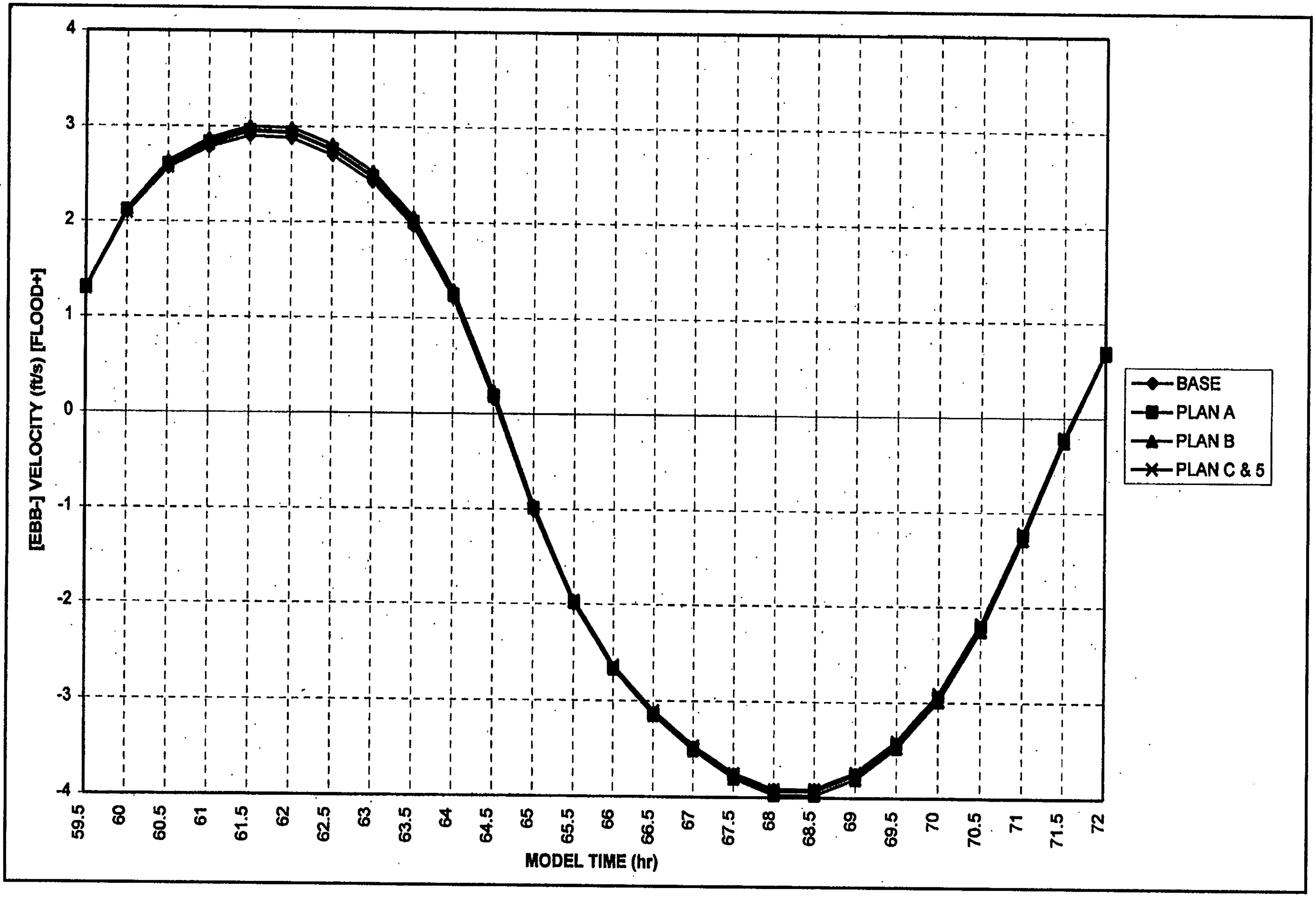

Figure A28. Velocity magnitude at station 7

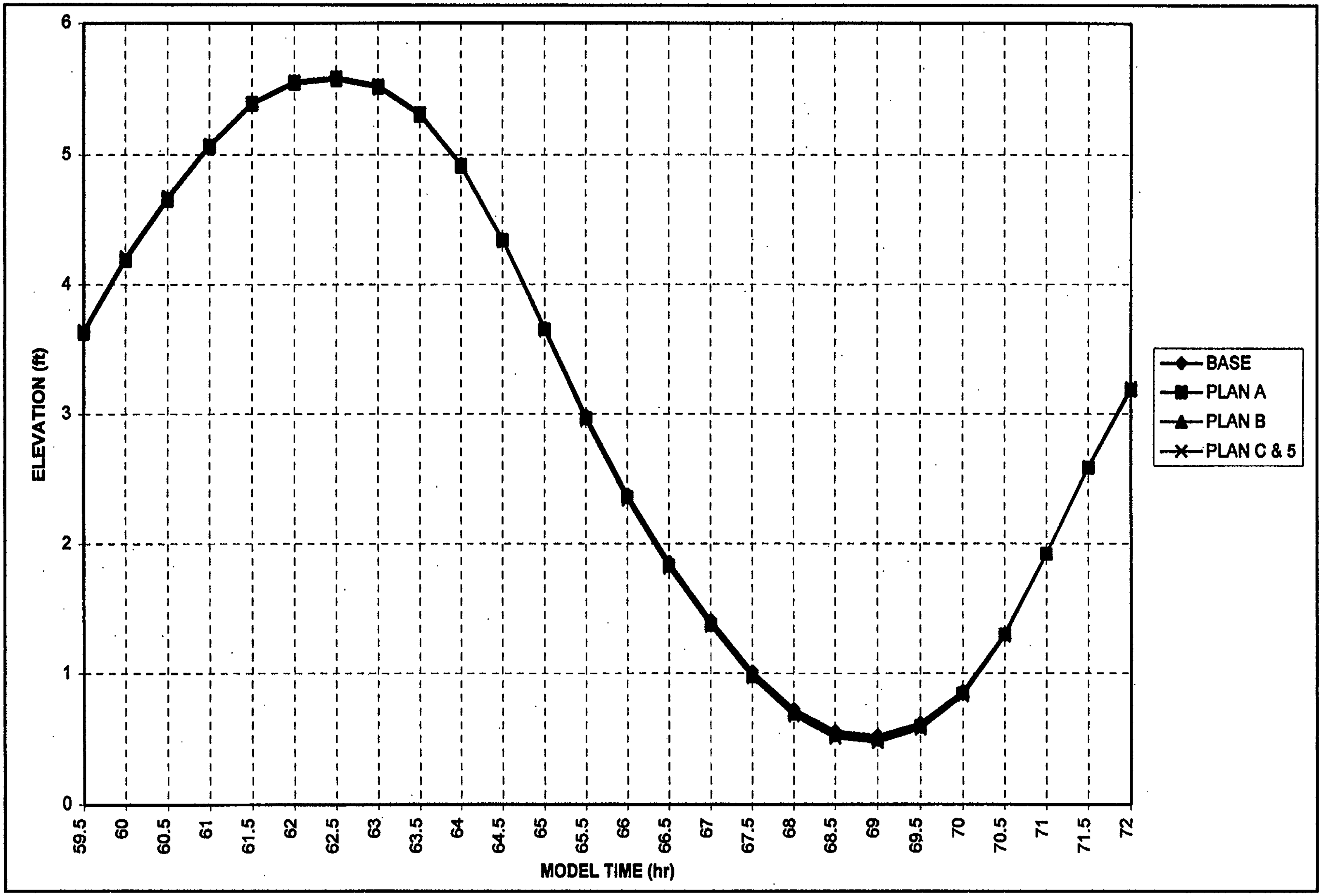

Figure A29. Water surface elevation at station 7

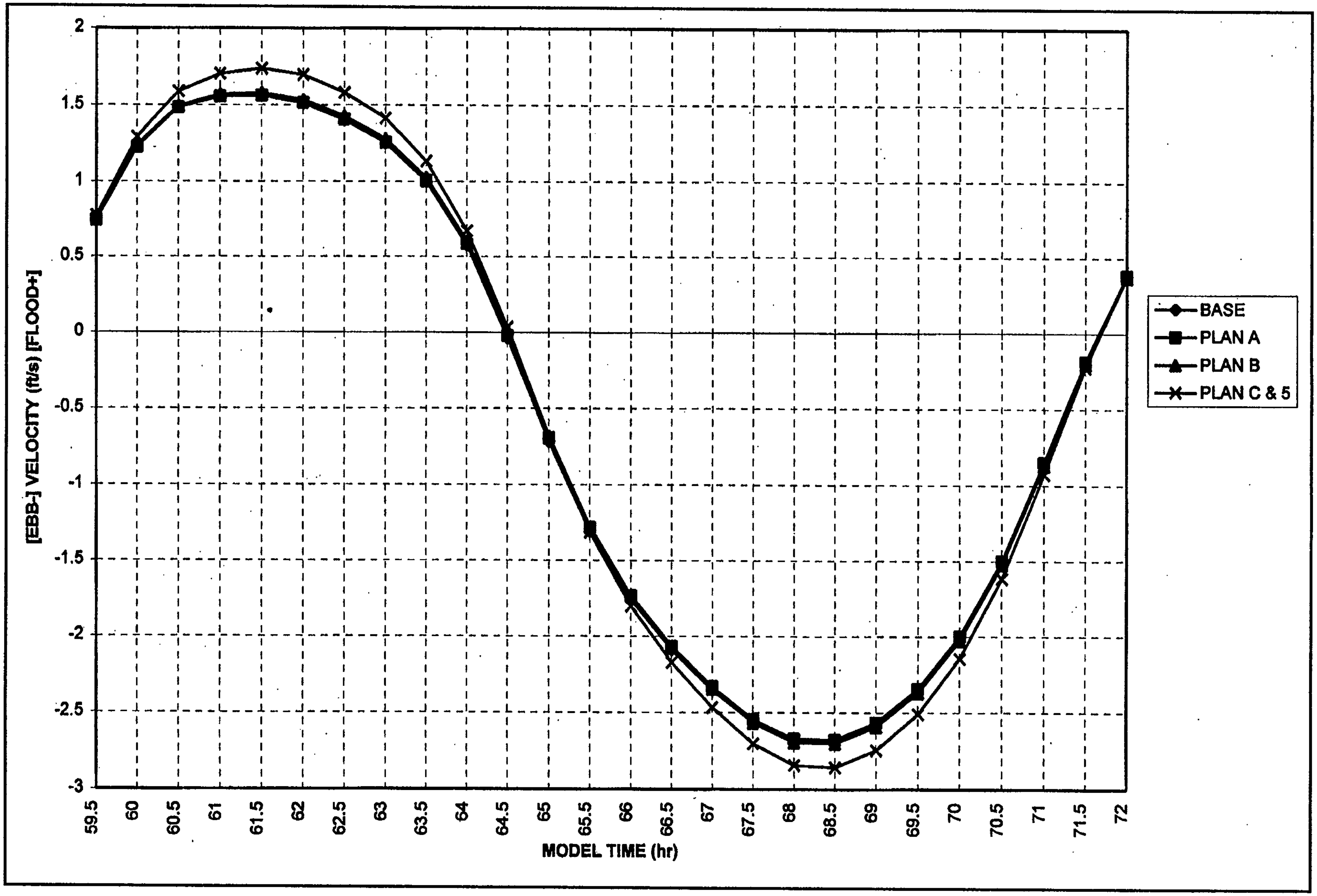

Figure A30. Velocity magnitude at station 8

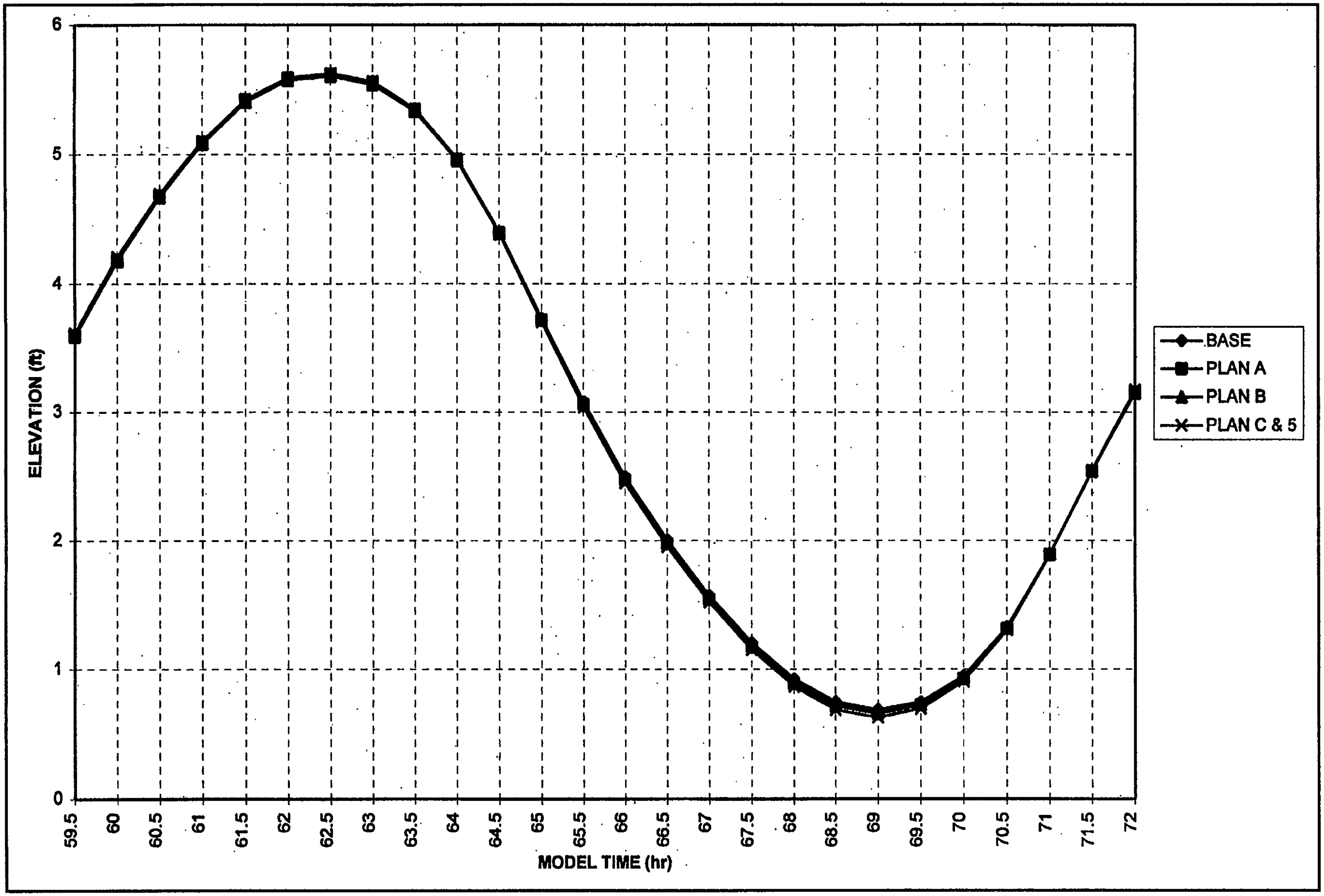

Figure A31. Water surface elevation at station 8

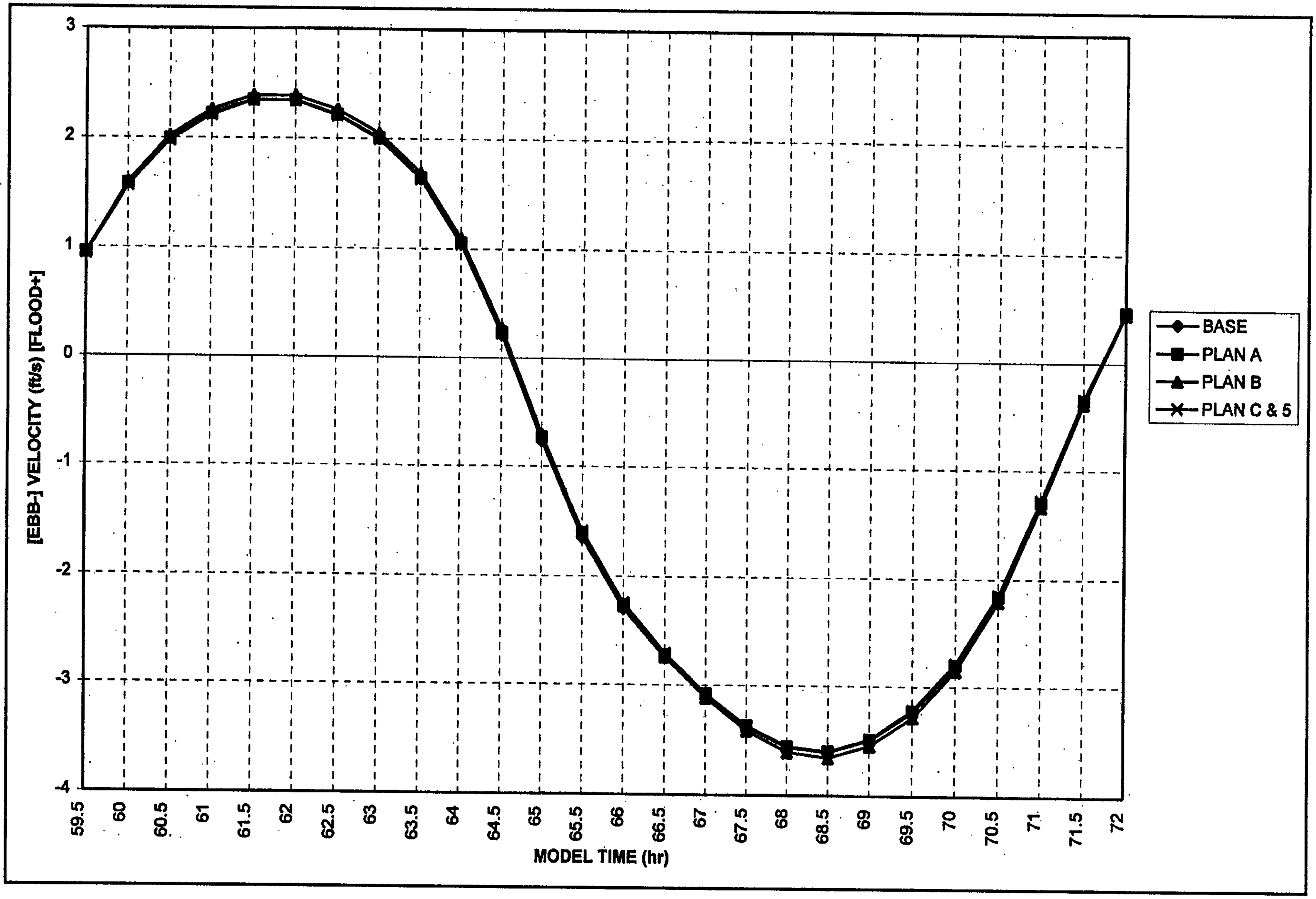

Figure A32. Velocity magnitude at station 9

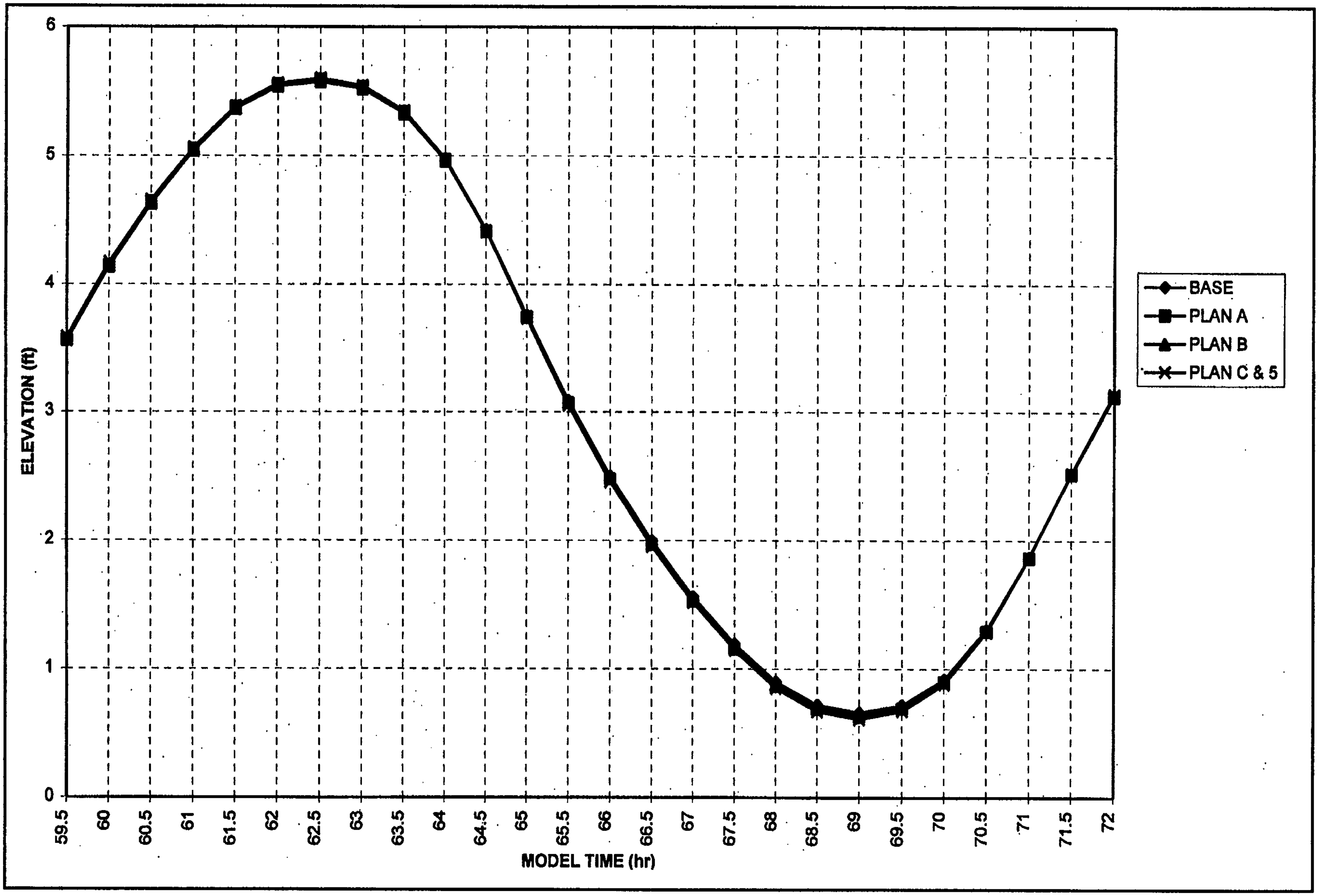

Figure A33. Water surface elevation at station 9

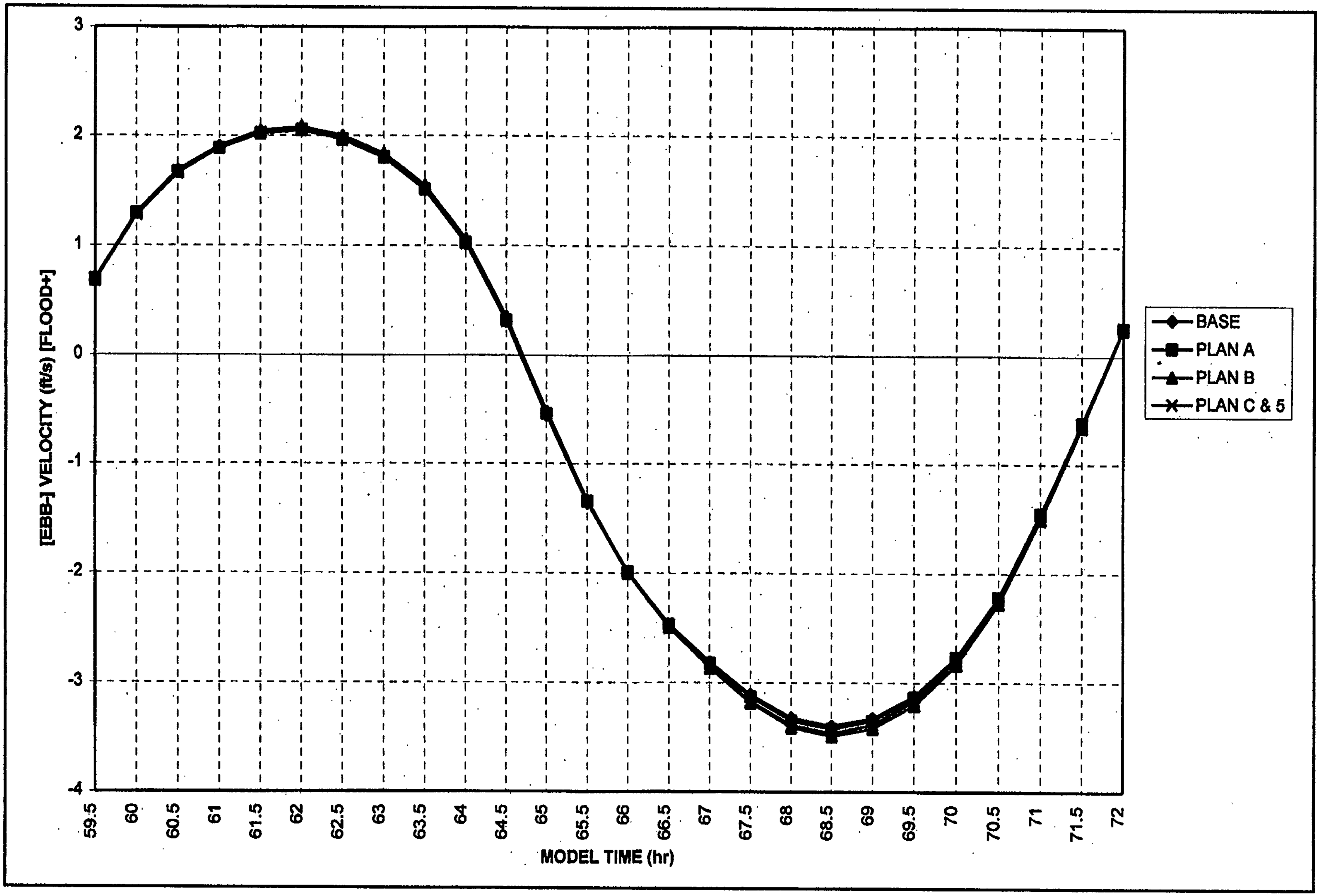

Figure A34. Velocity magnitude at station 10

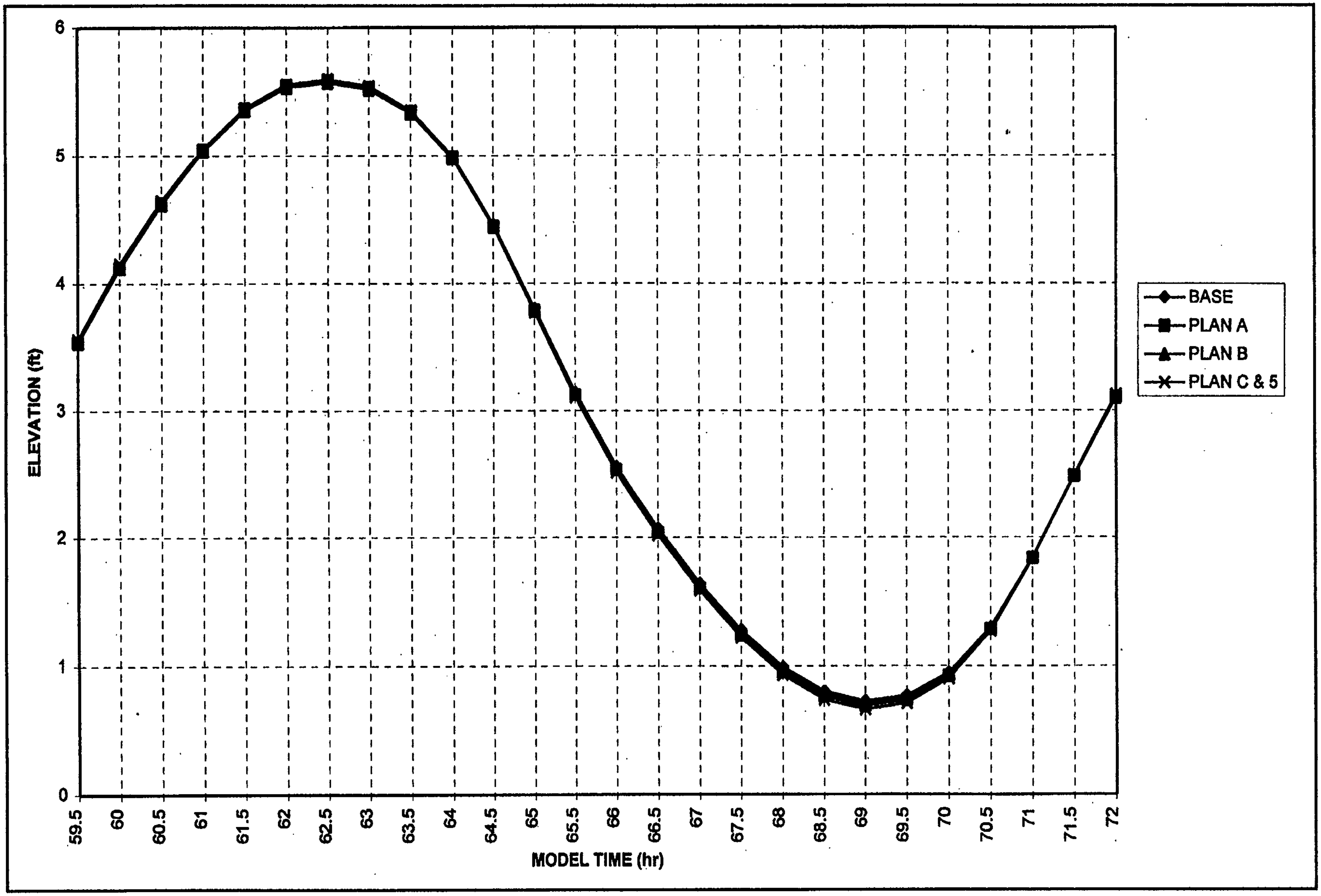

Figure A35. Water surface elevation at station 10

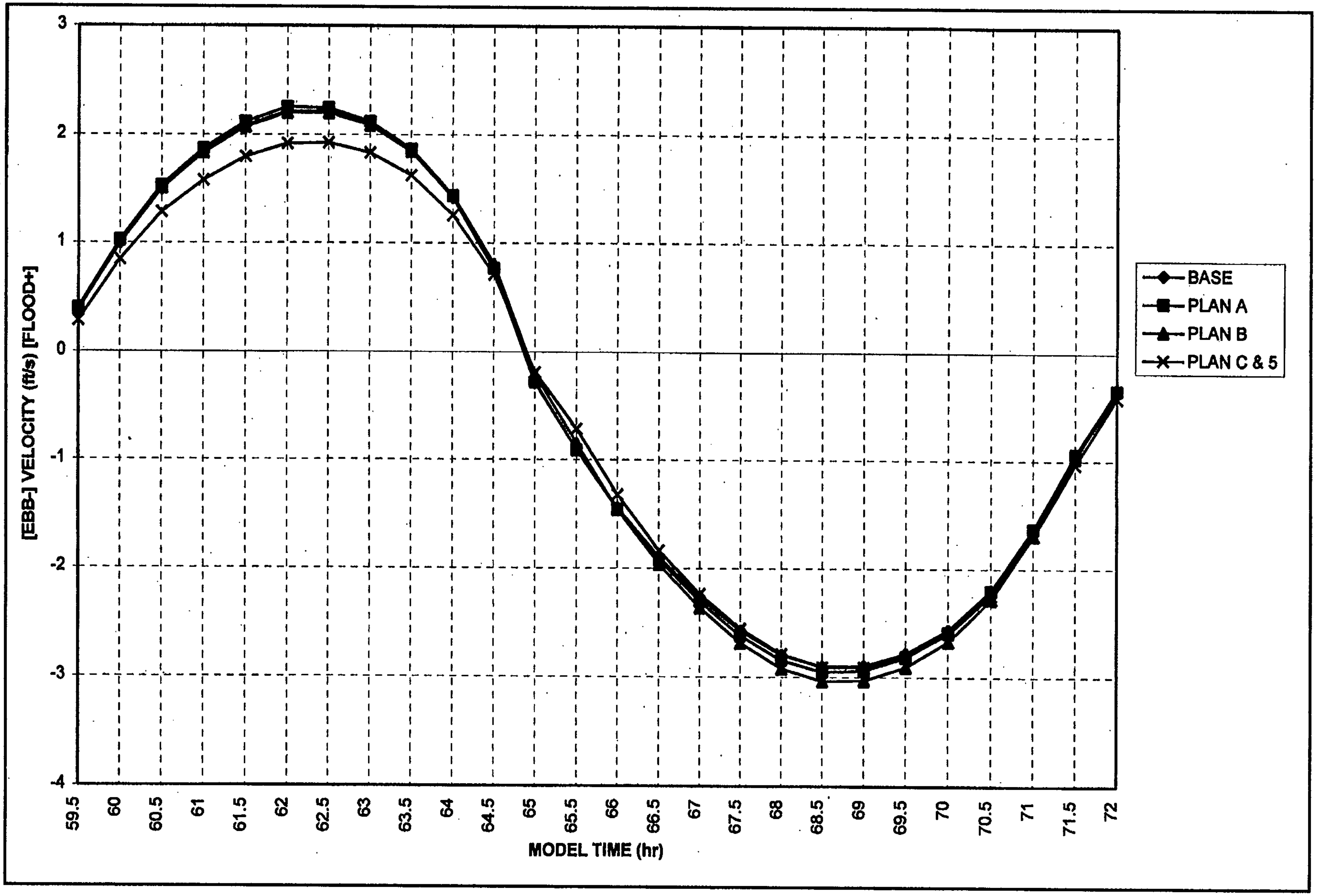

Figure A36. Velocity magnitude at station 11

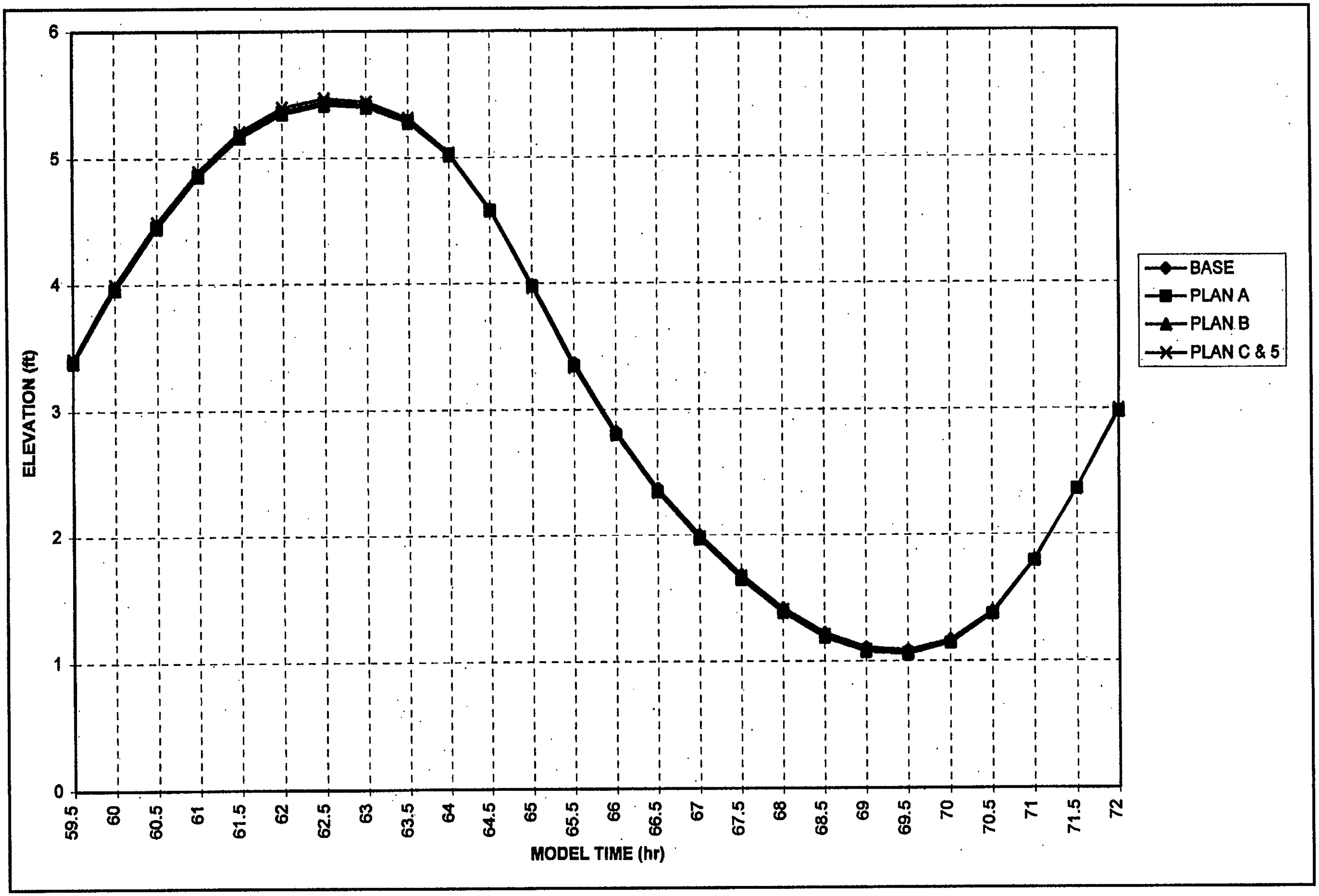

Figure A37. Water surface elevation at station 11

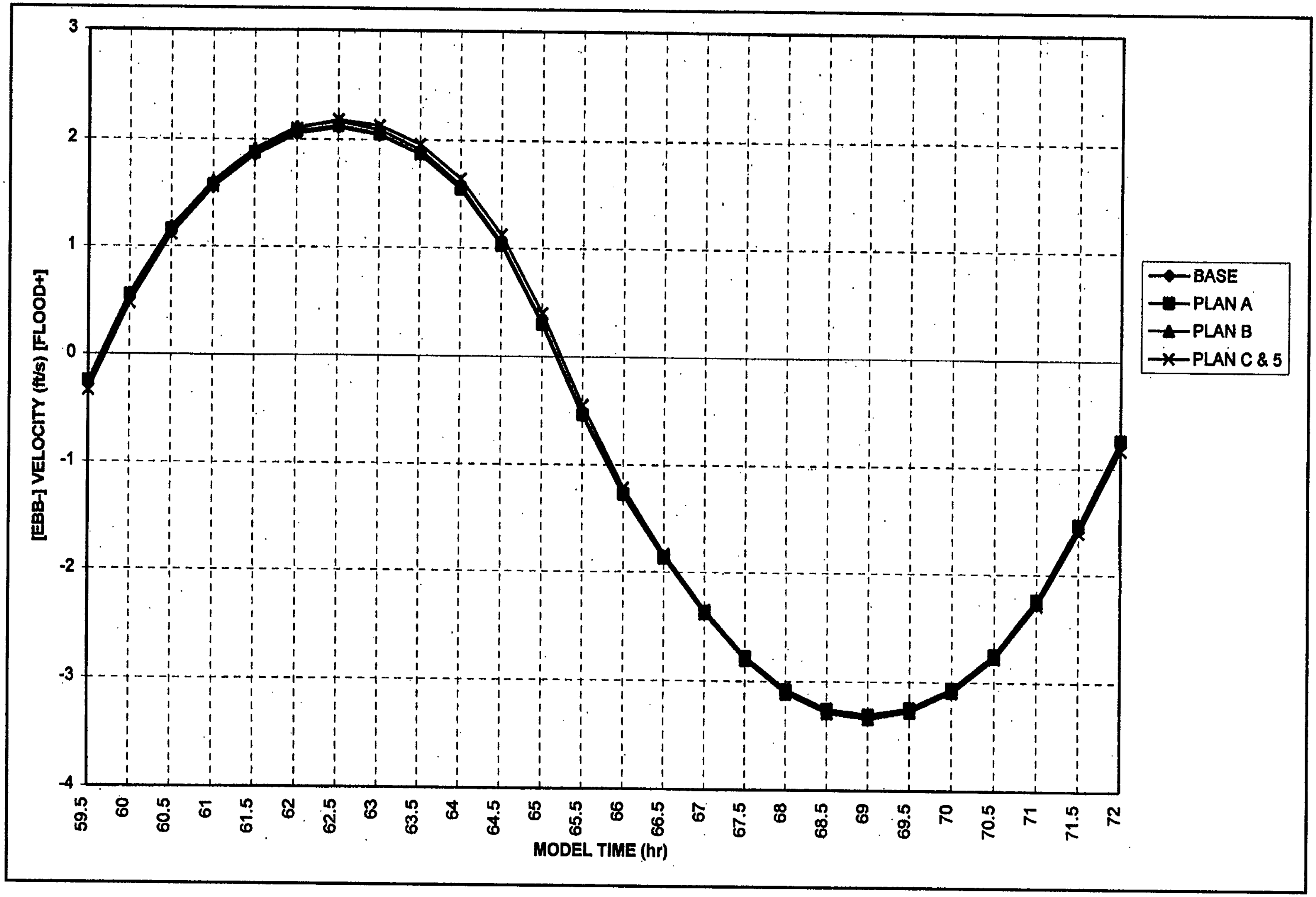

Figure A38. Velocity magnitude at station 12

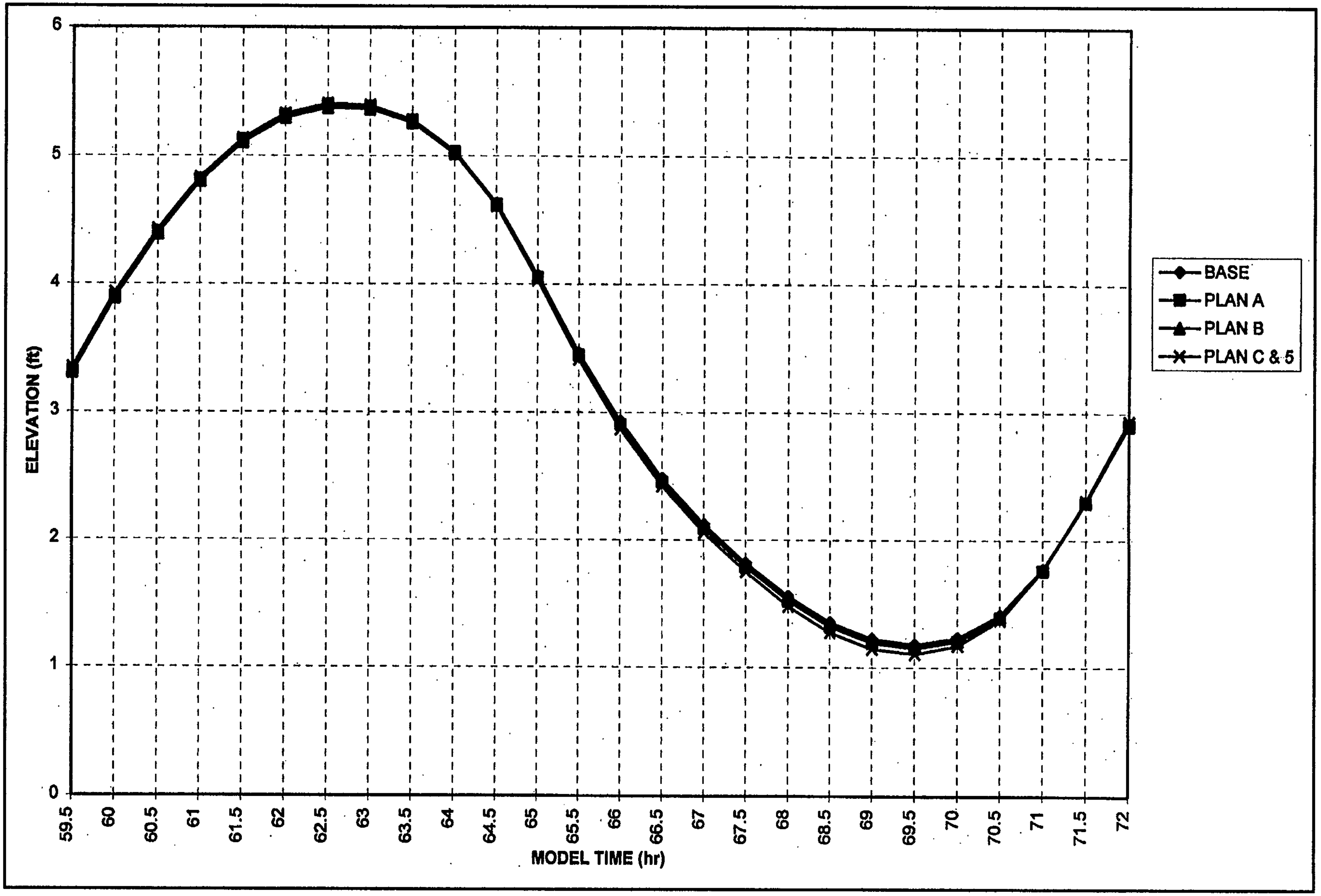

Figure A39. Water surface elevation at station 12

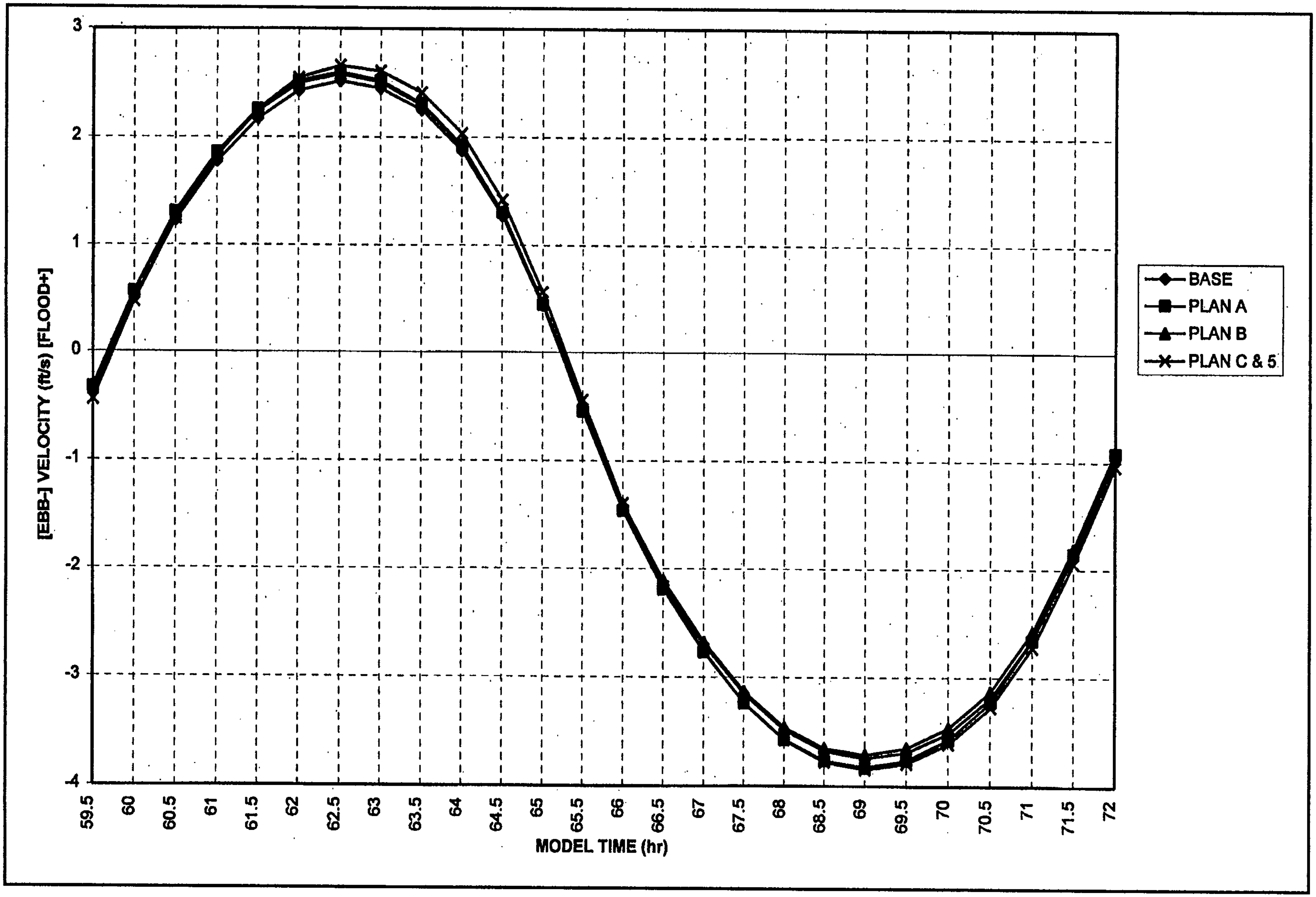

Figure A40. Velocity magnitude at station 13

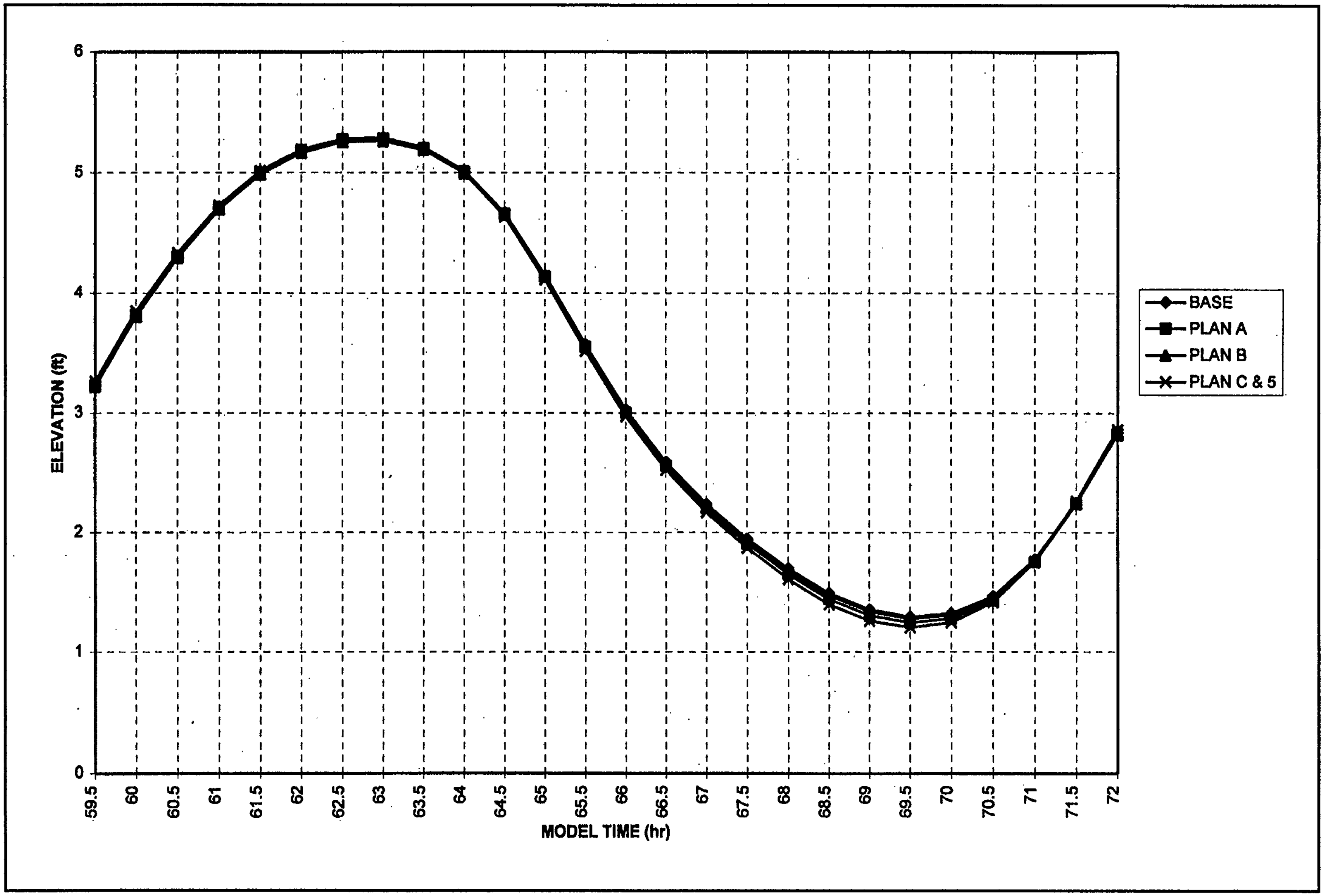

Figure A41. Water surface elevation at station 13

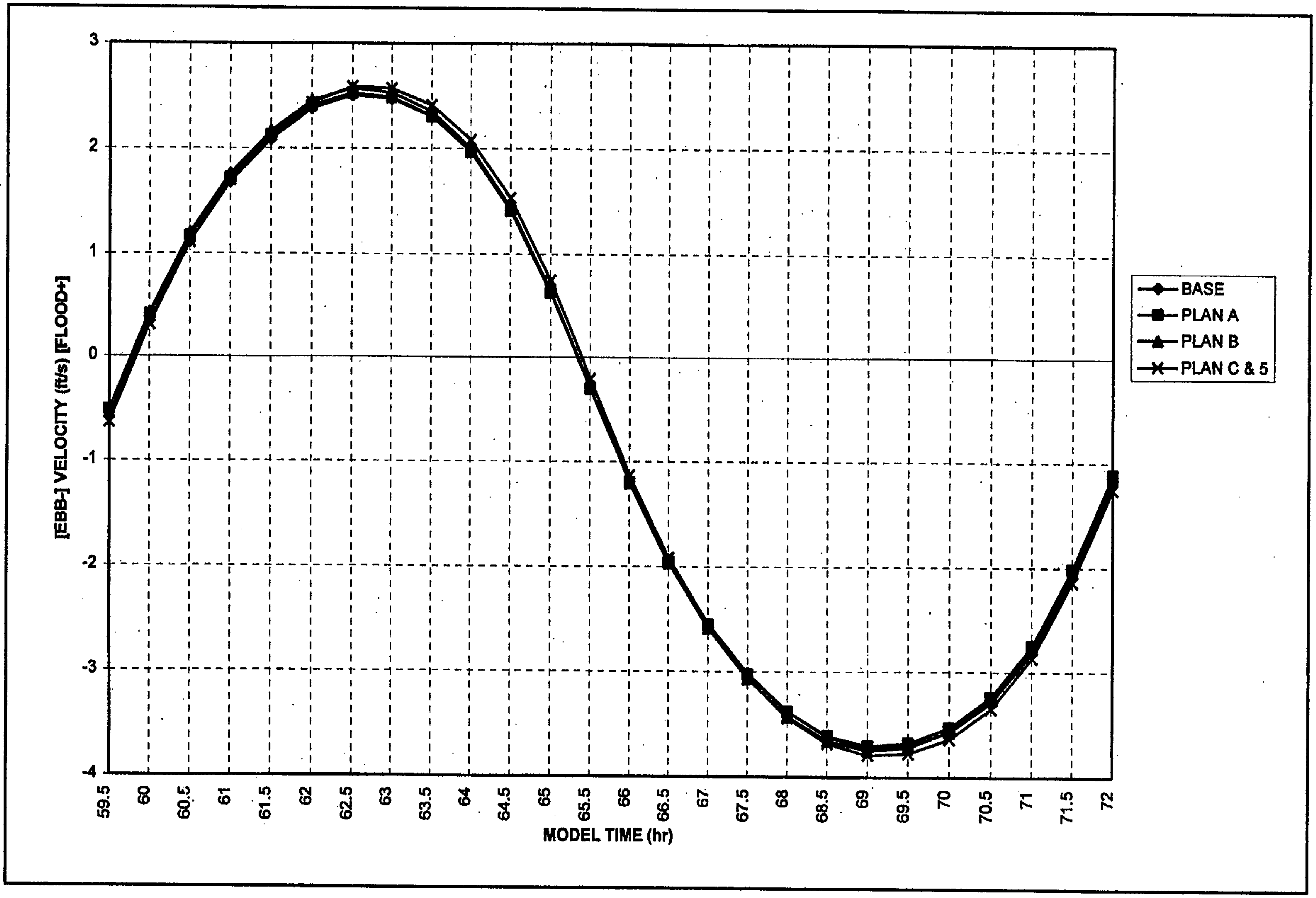

Figure A42. Velocity magnitude at station 14

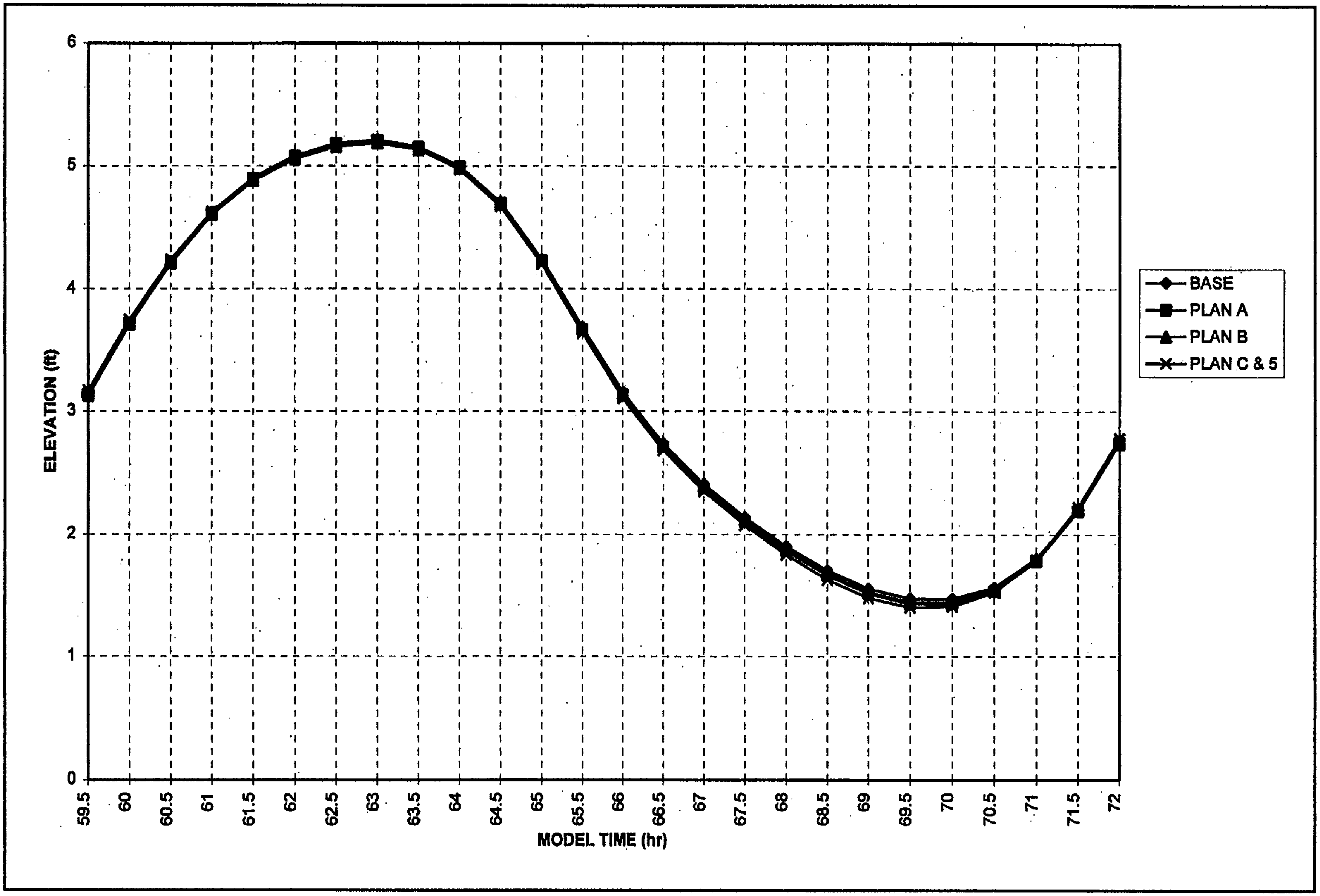

Figure A43. Water surface elevation at station 14

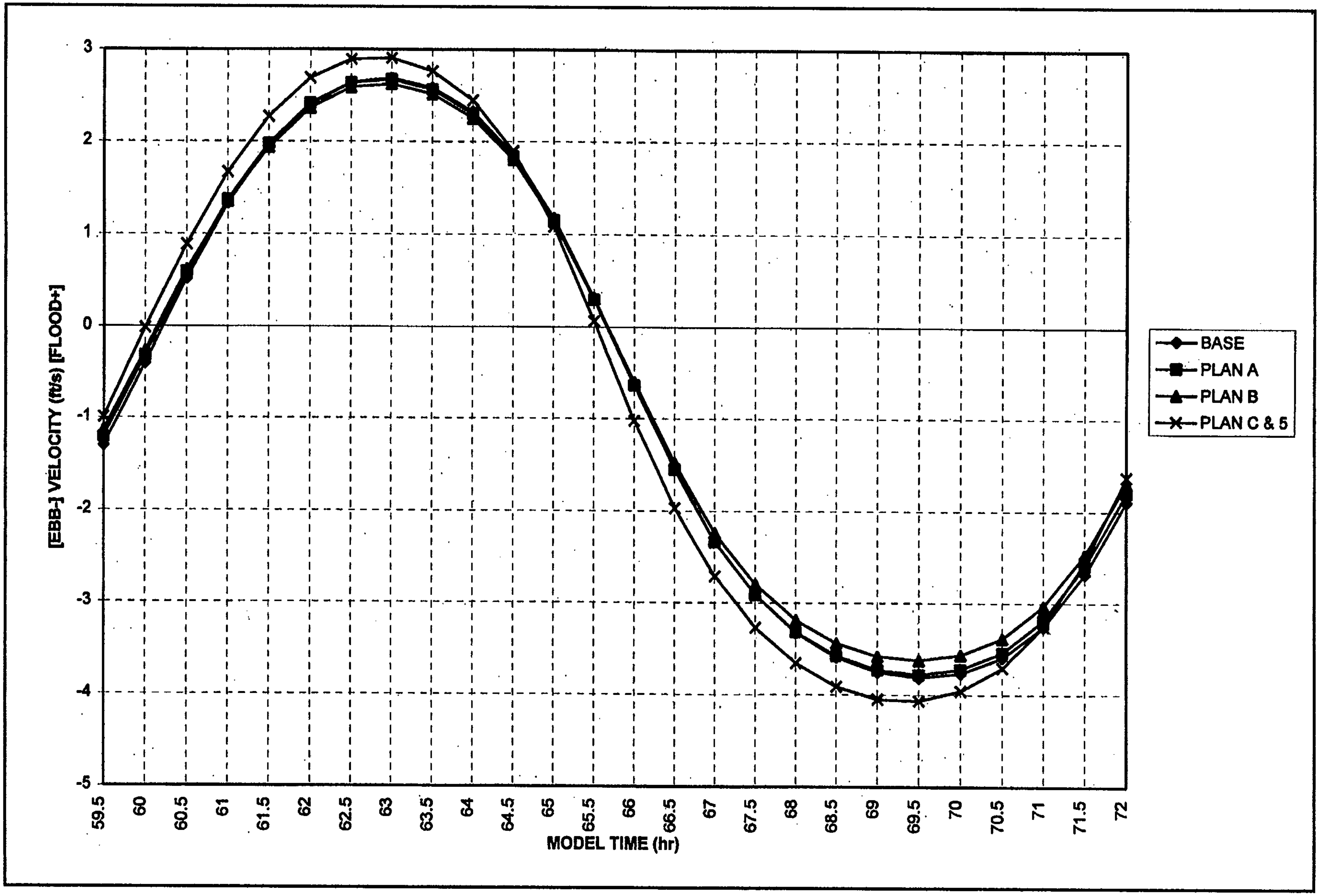

Figure A44. Velocity magnitude at station 15

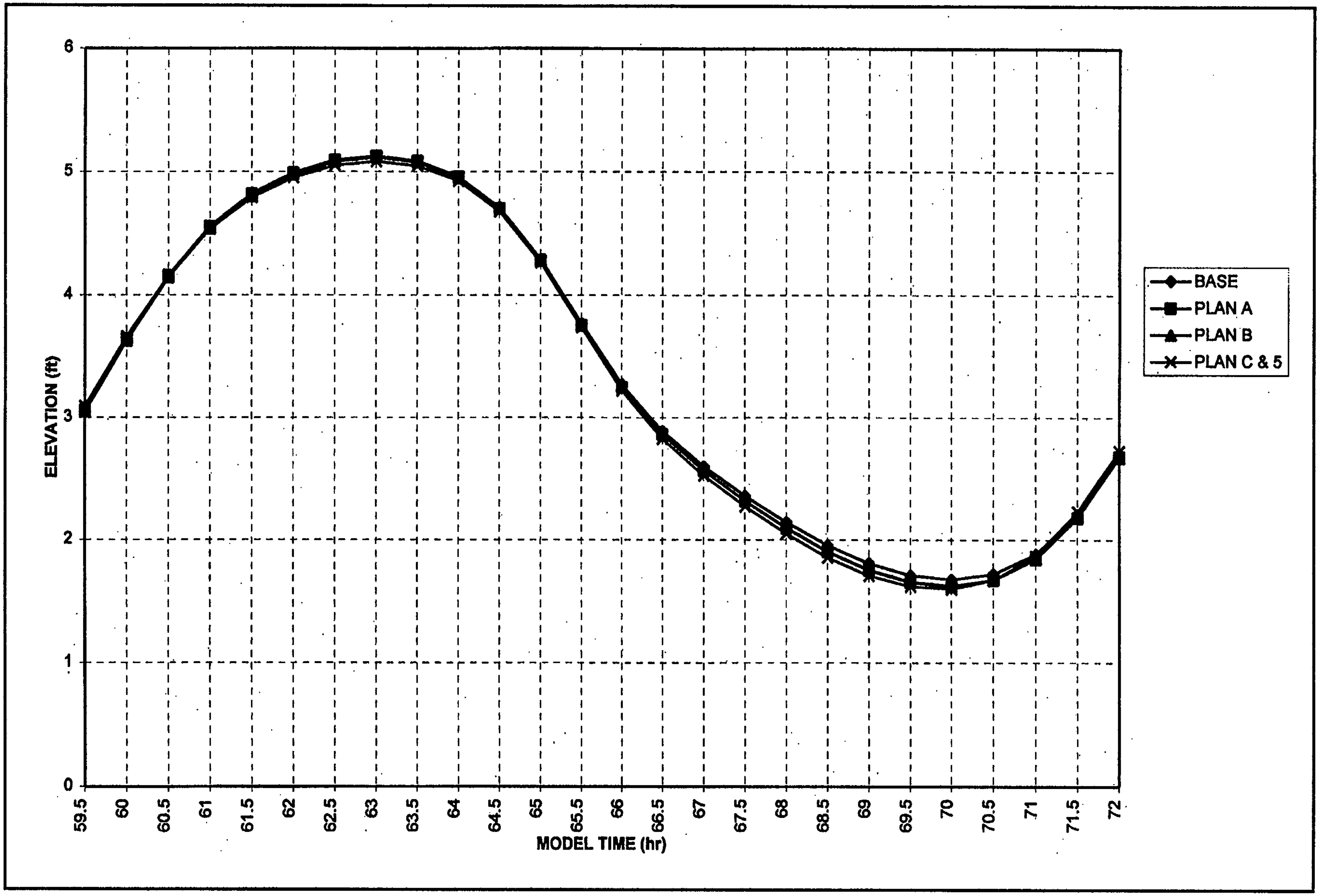

Figure A45. Water surface elevation at station 15

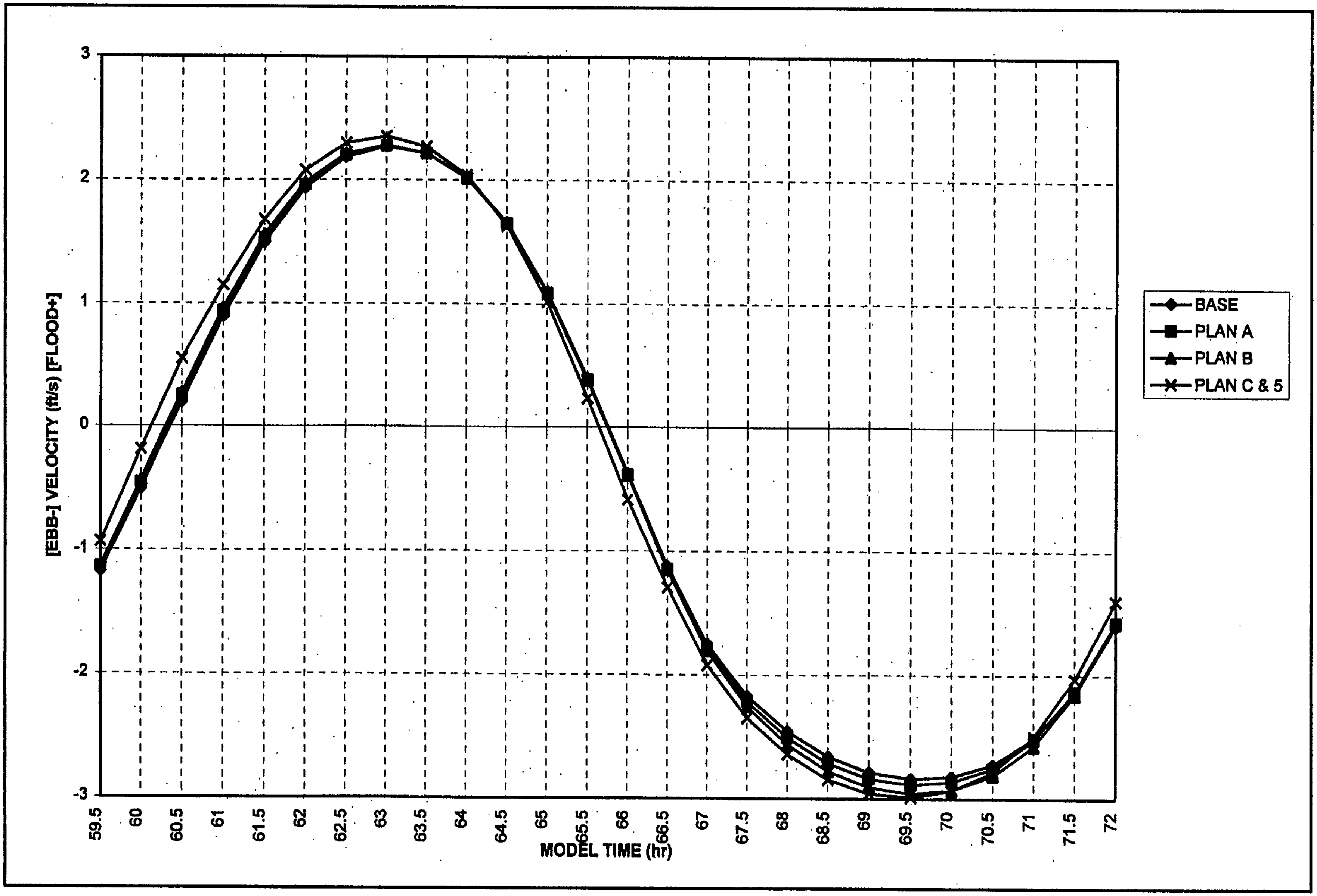

Figure A46. Velocity magnitude at station 16

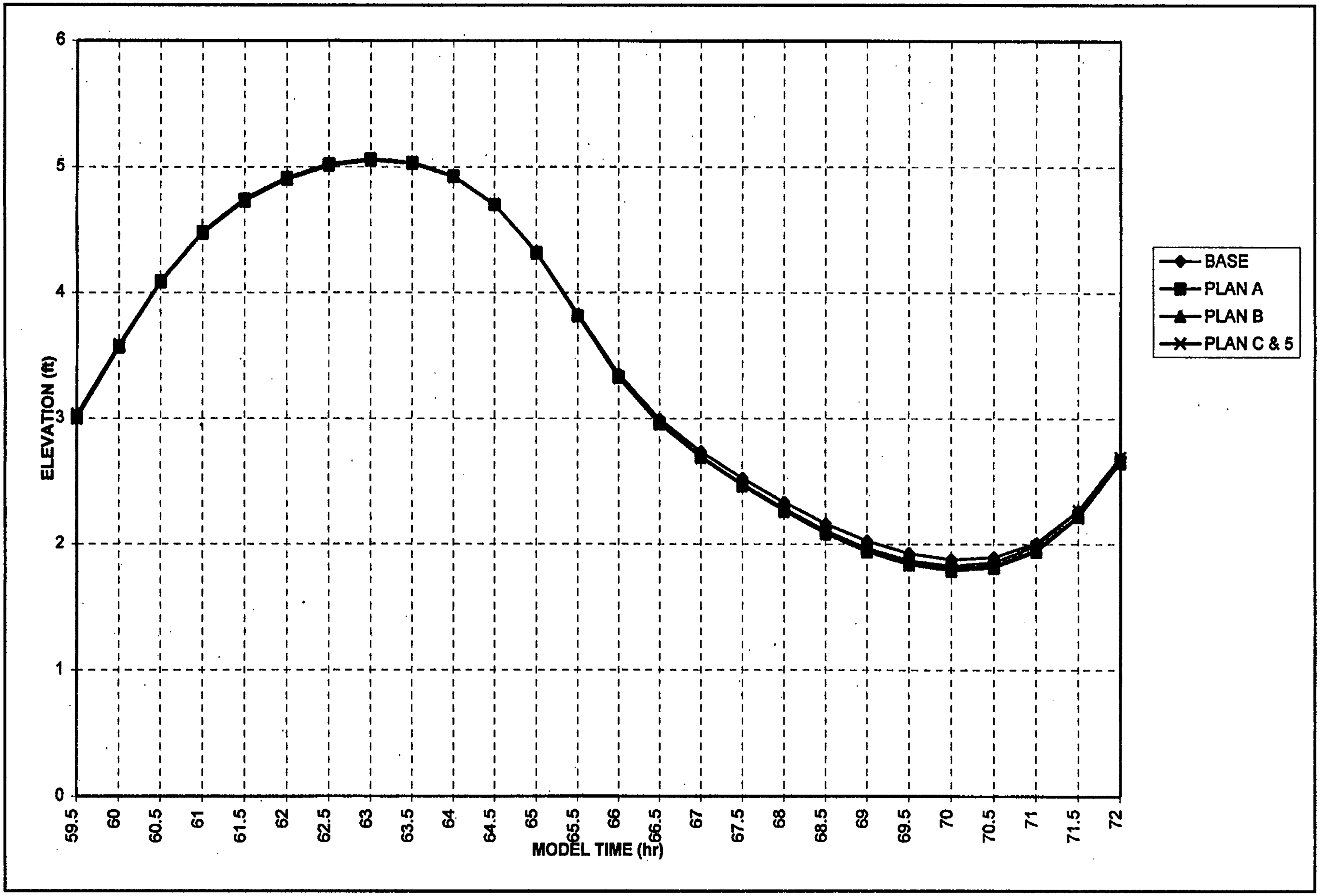

Figure A47. Water surface elevation at station 16

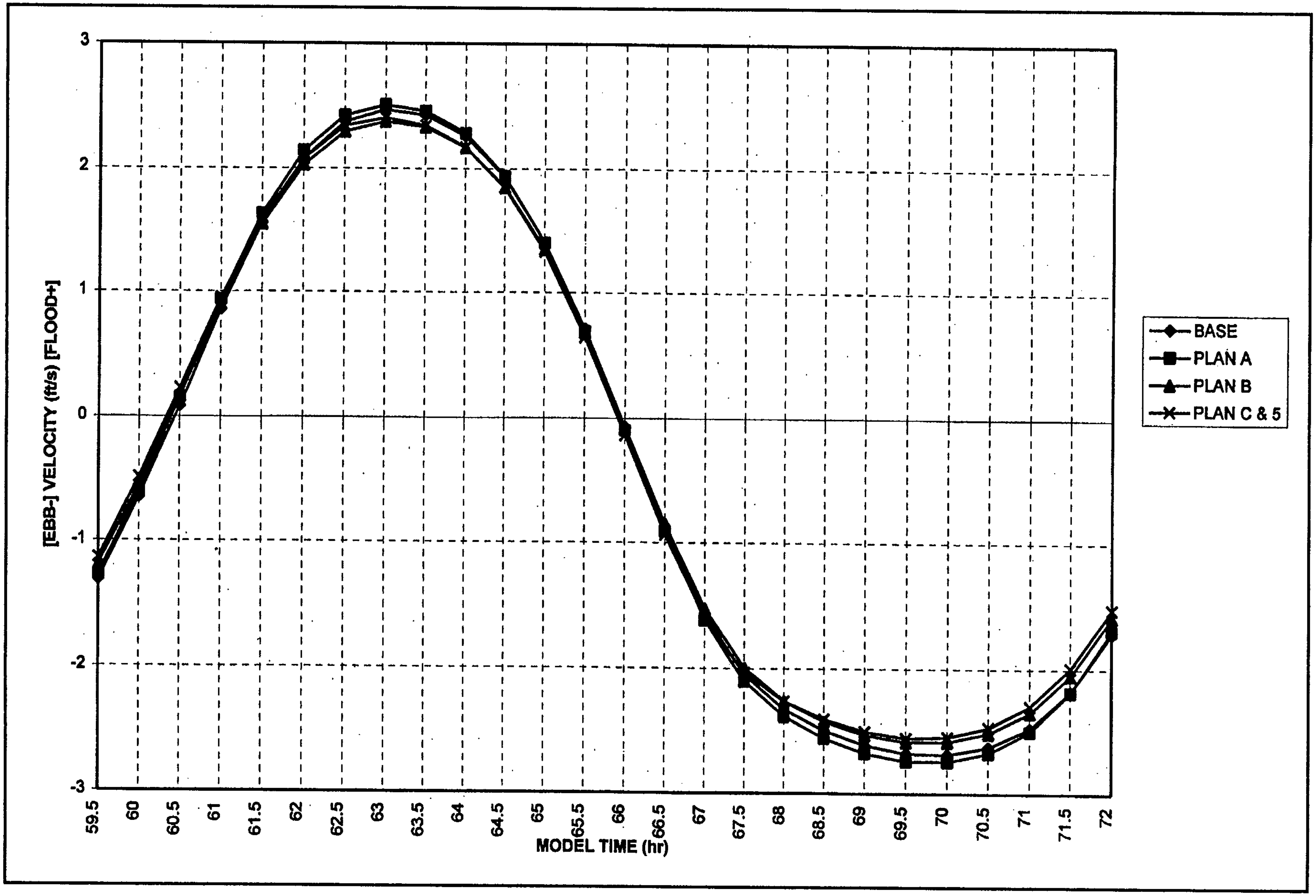

Figure A48. Velocity magnitude at station 17

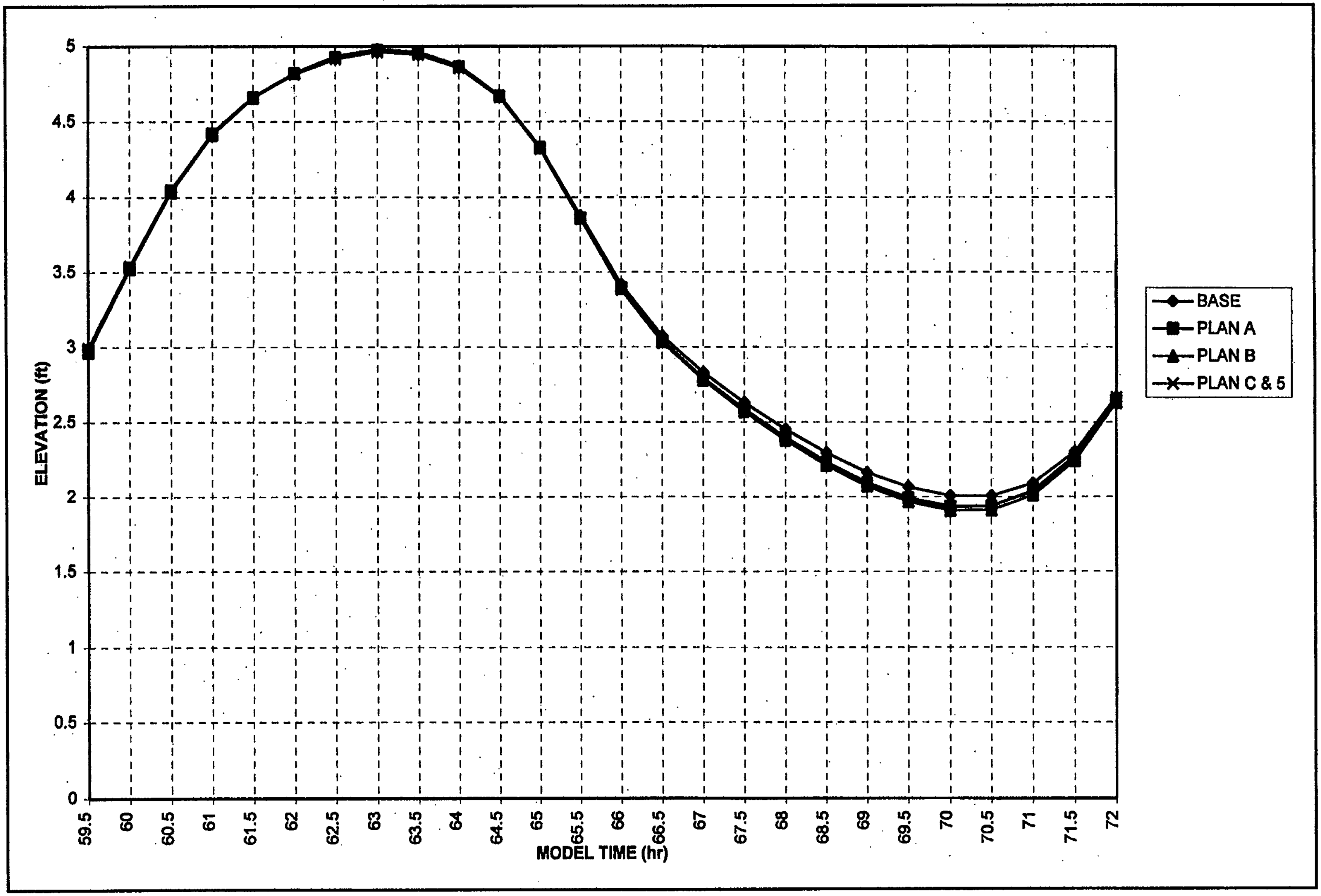

Figure A49. Water surface elevation at station 17

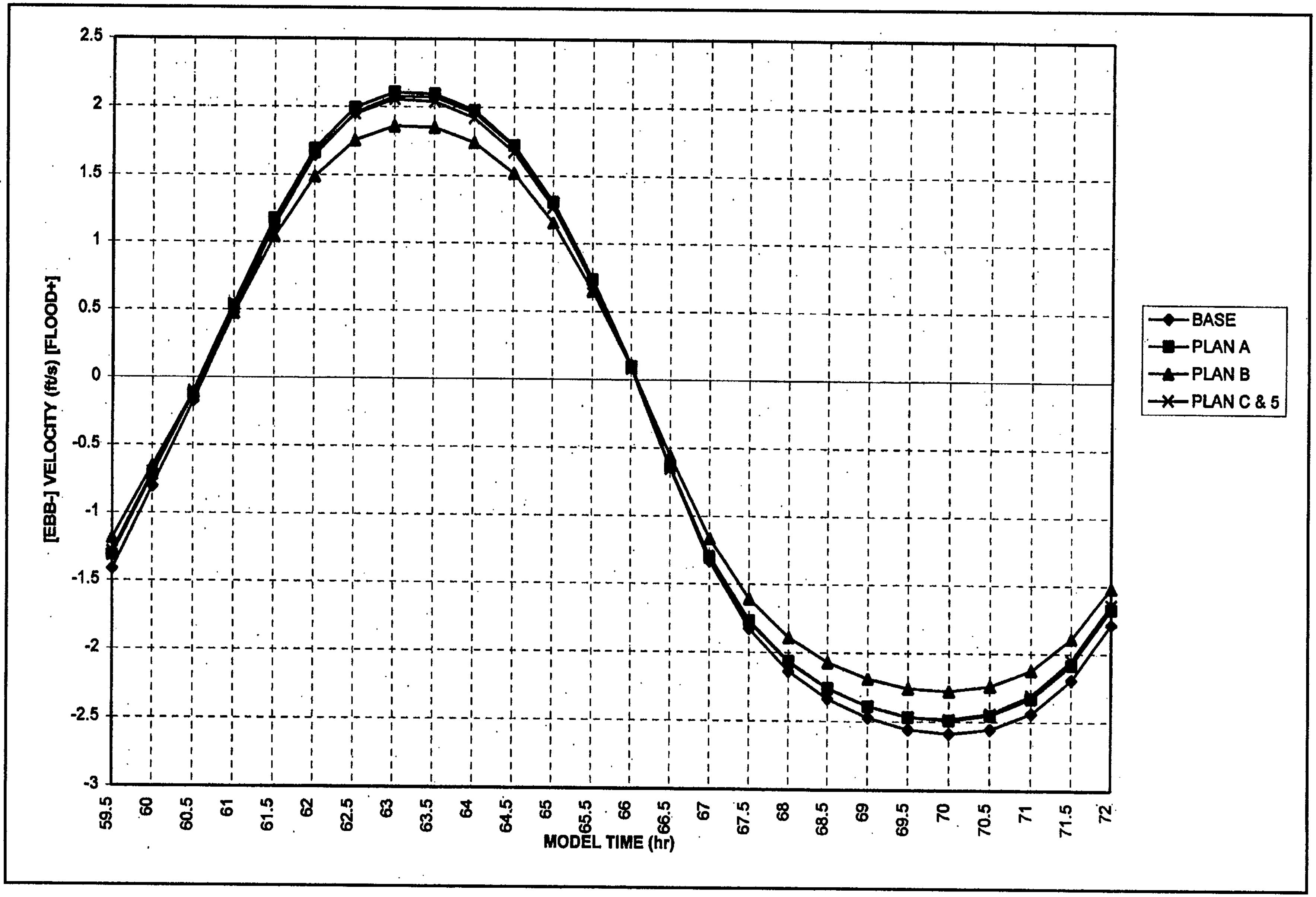

Figure A50. Velocity magnitude at station 18

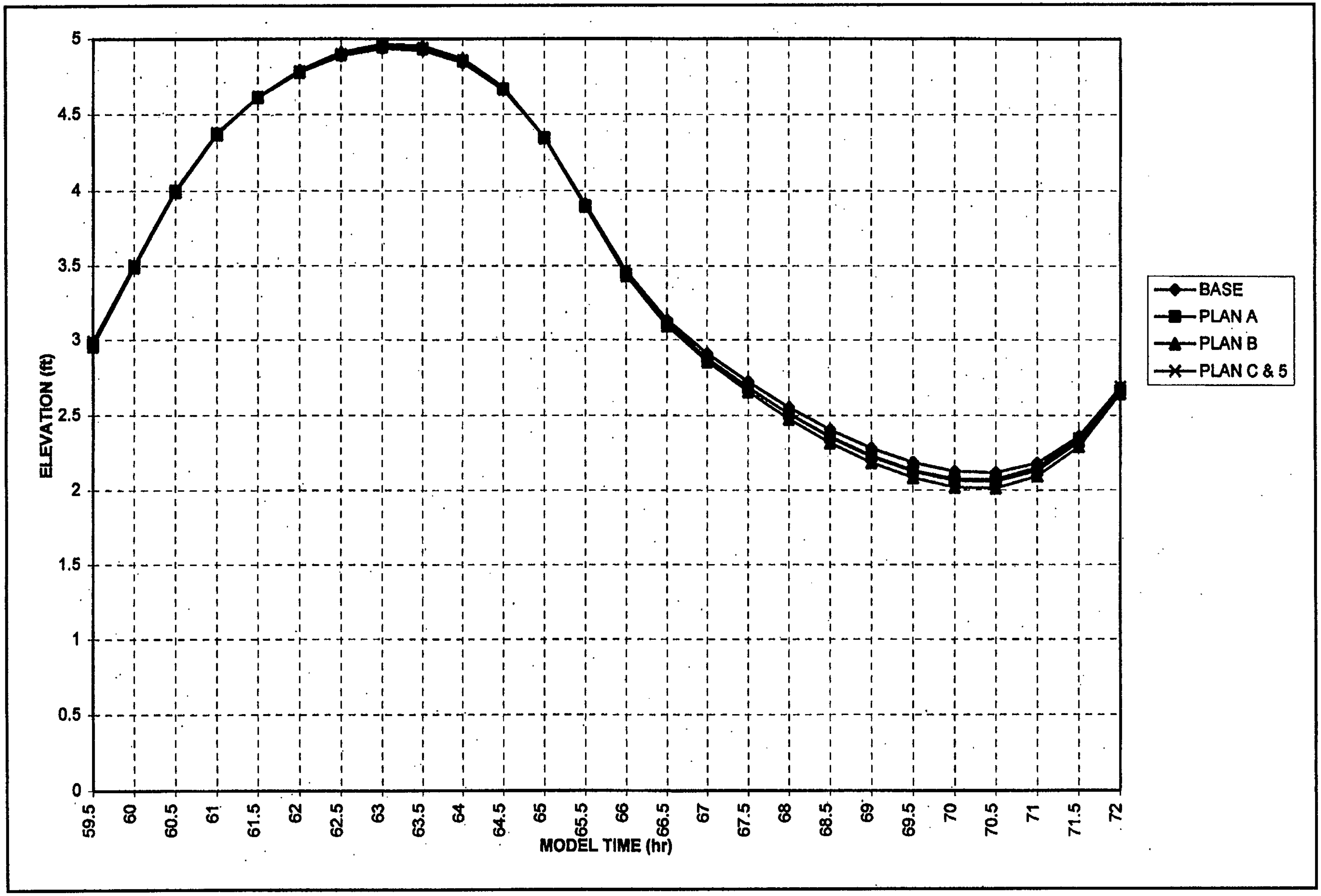

Figure A51. Water surface elevation at station 18

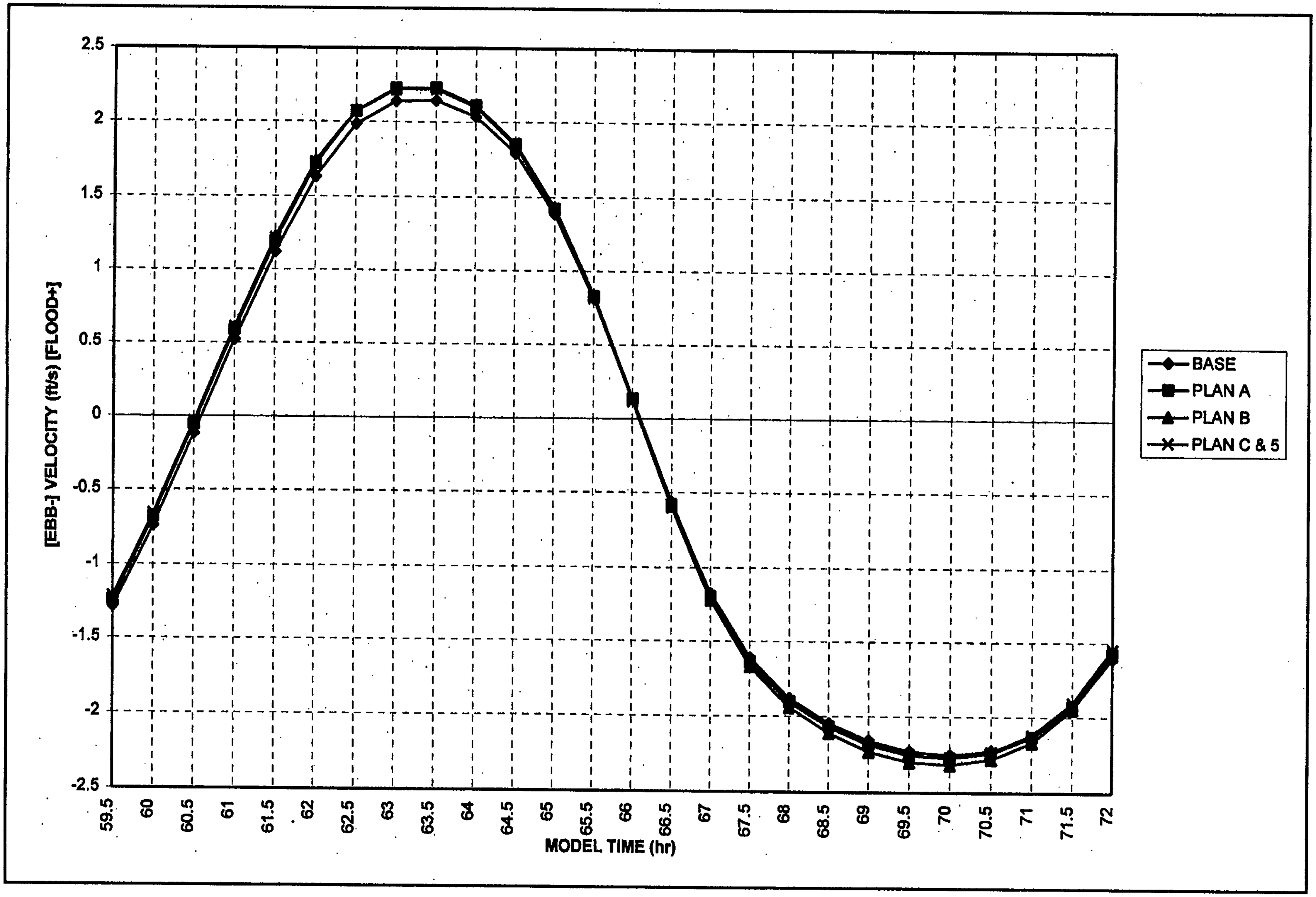

Figure A52. Velocity magnitude at station 19

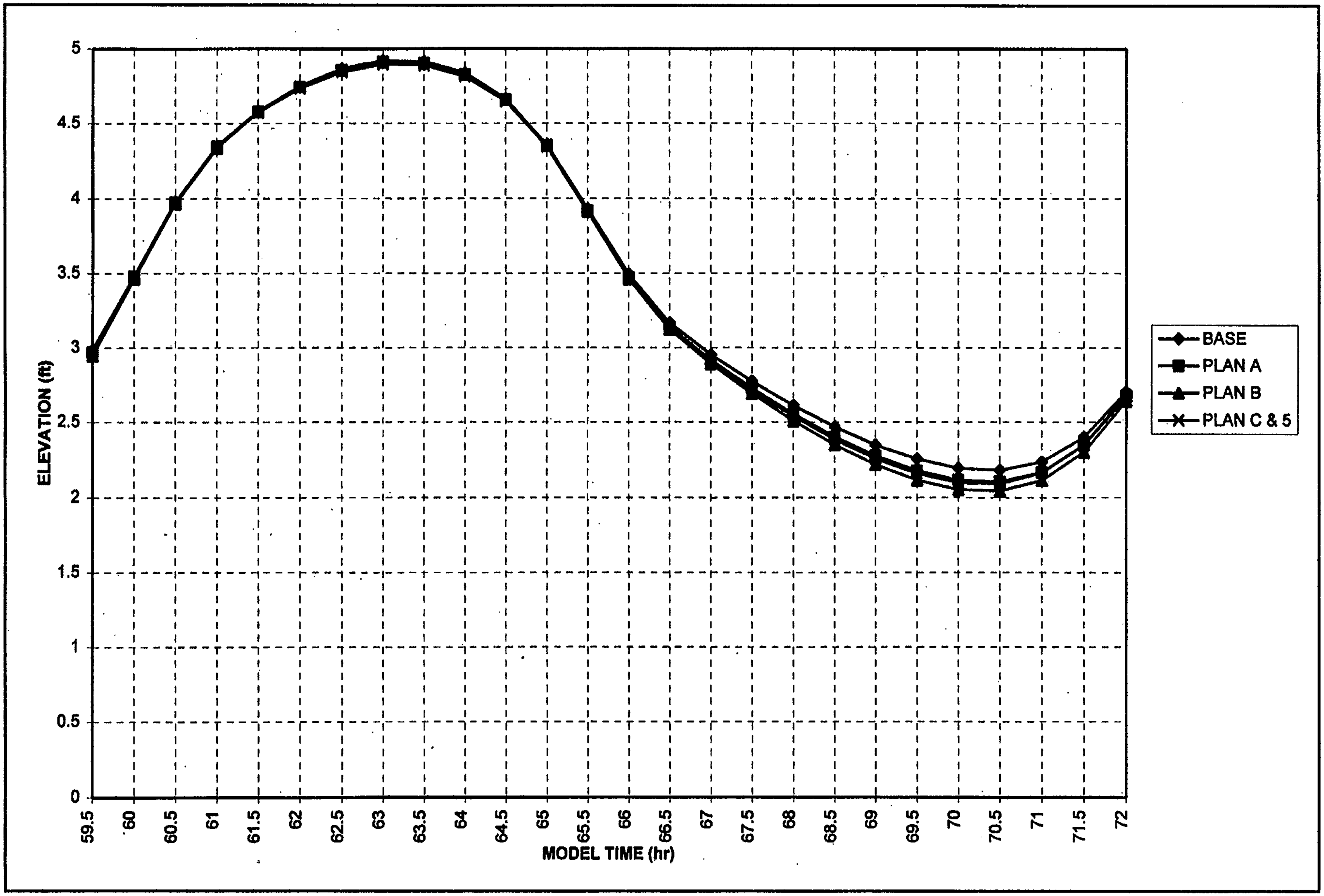

Figure A53. Water surface elevation at station 19

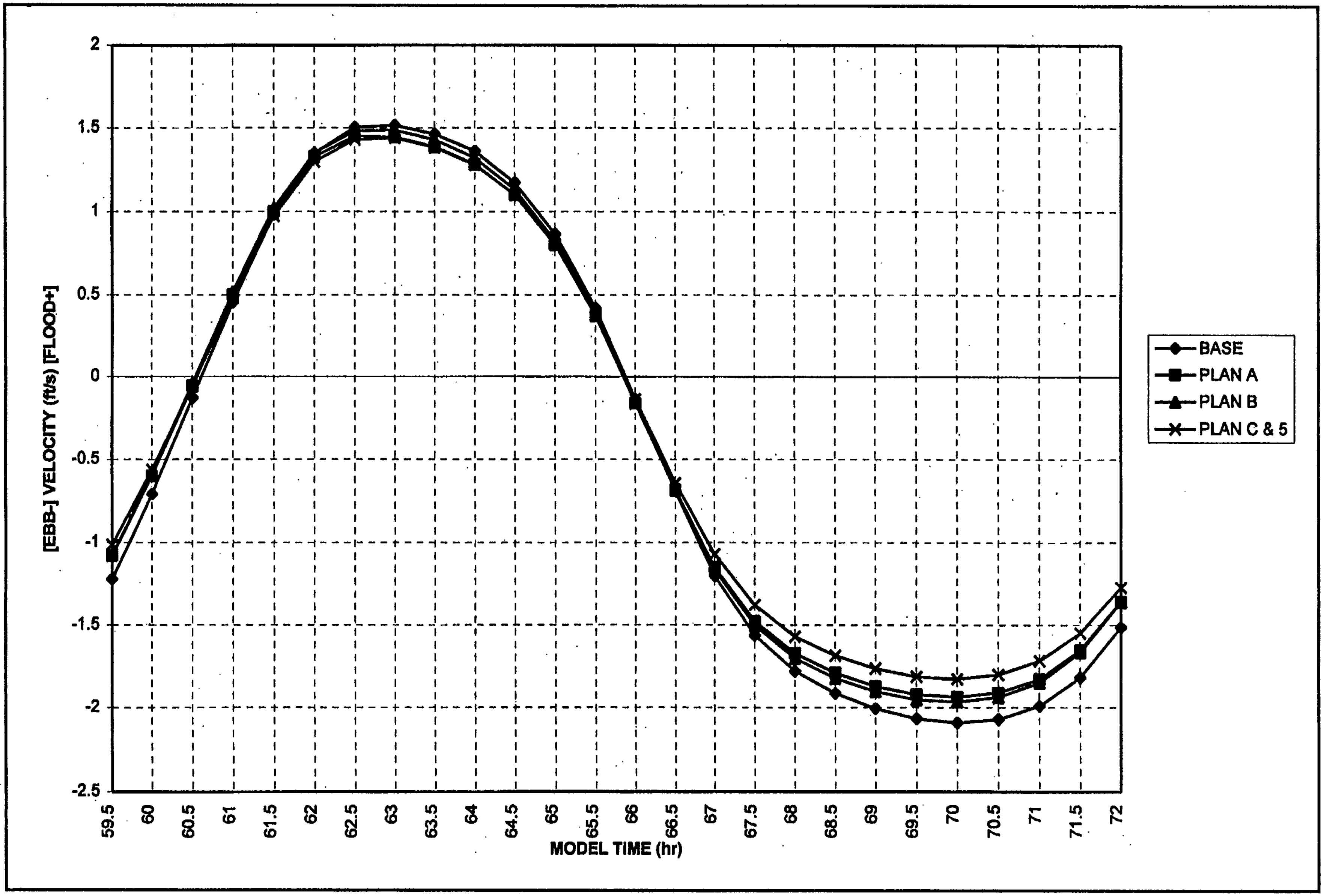

Figure A54. Velocity magnitude at station 20

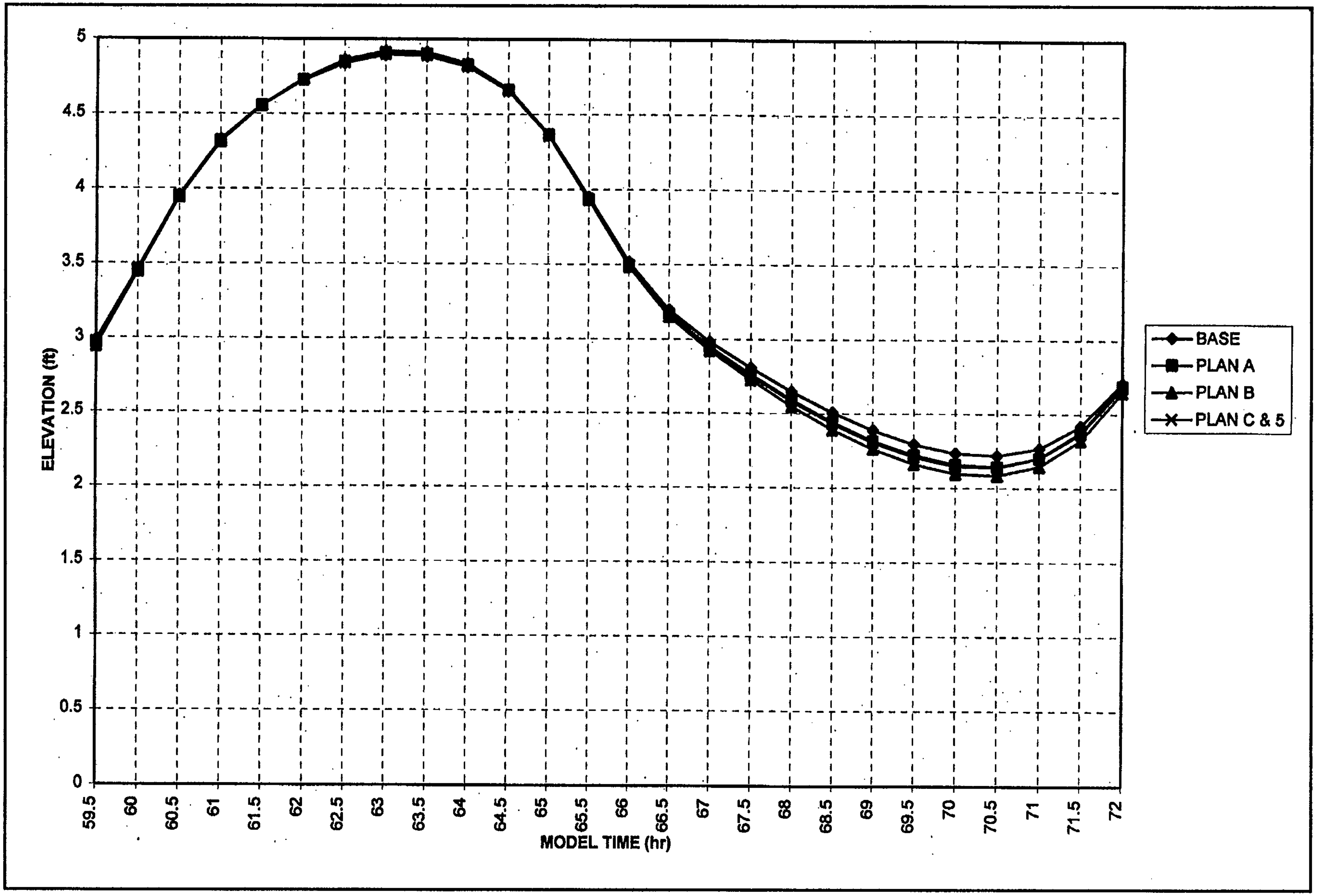

Figure A55. Water surface elevation at station 20

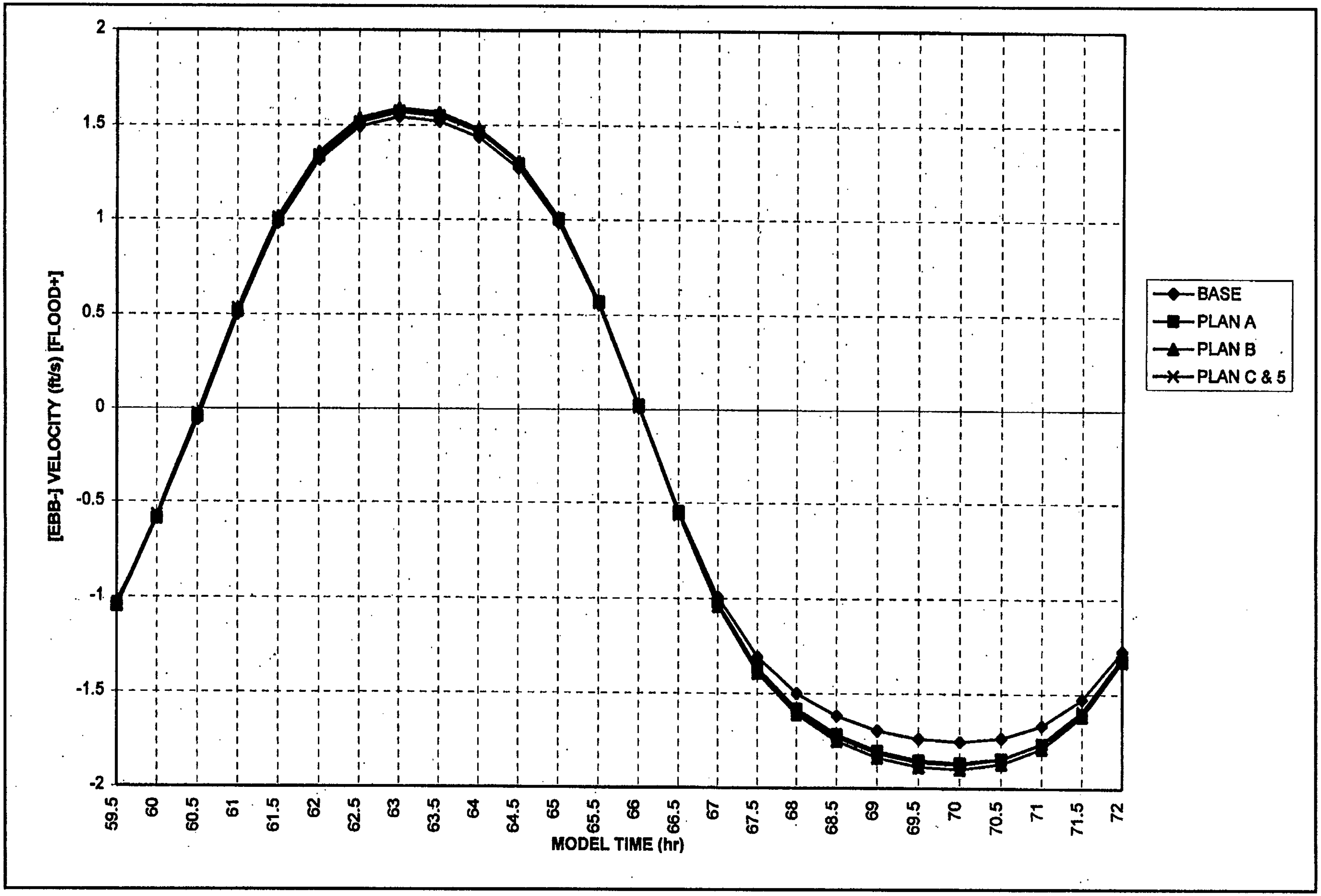

Figure A56. Velocity magnitude at station 21

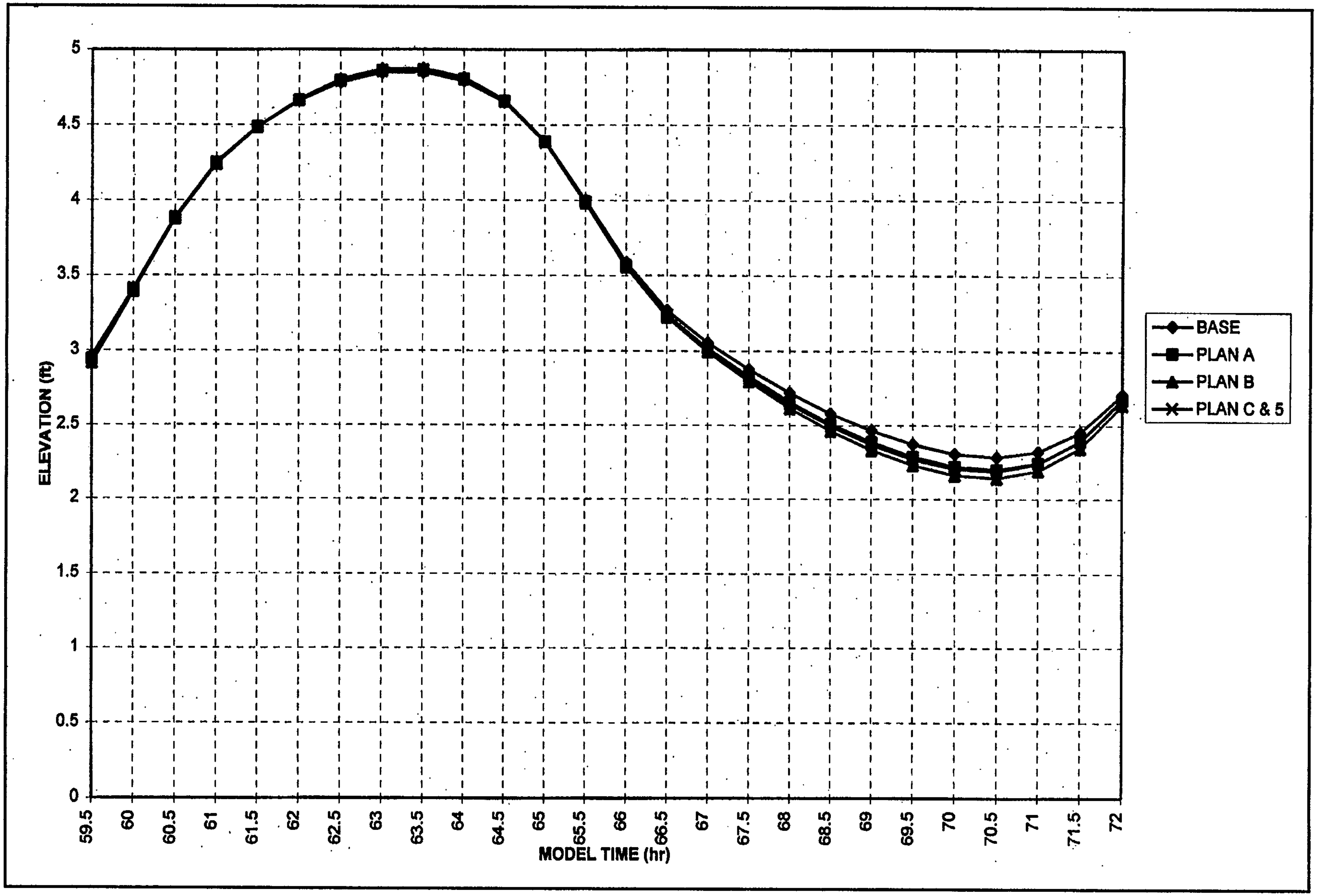

Figure A57. Water surface elevation at station 21

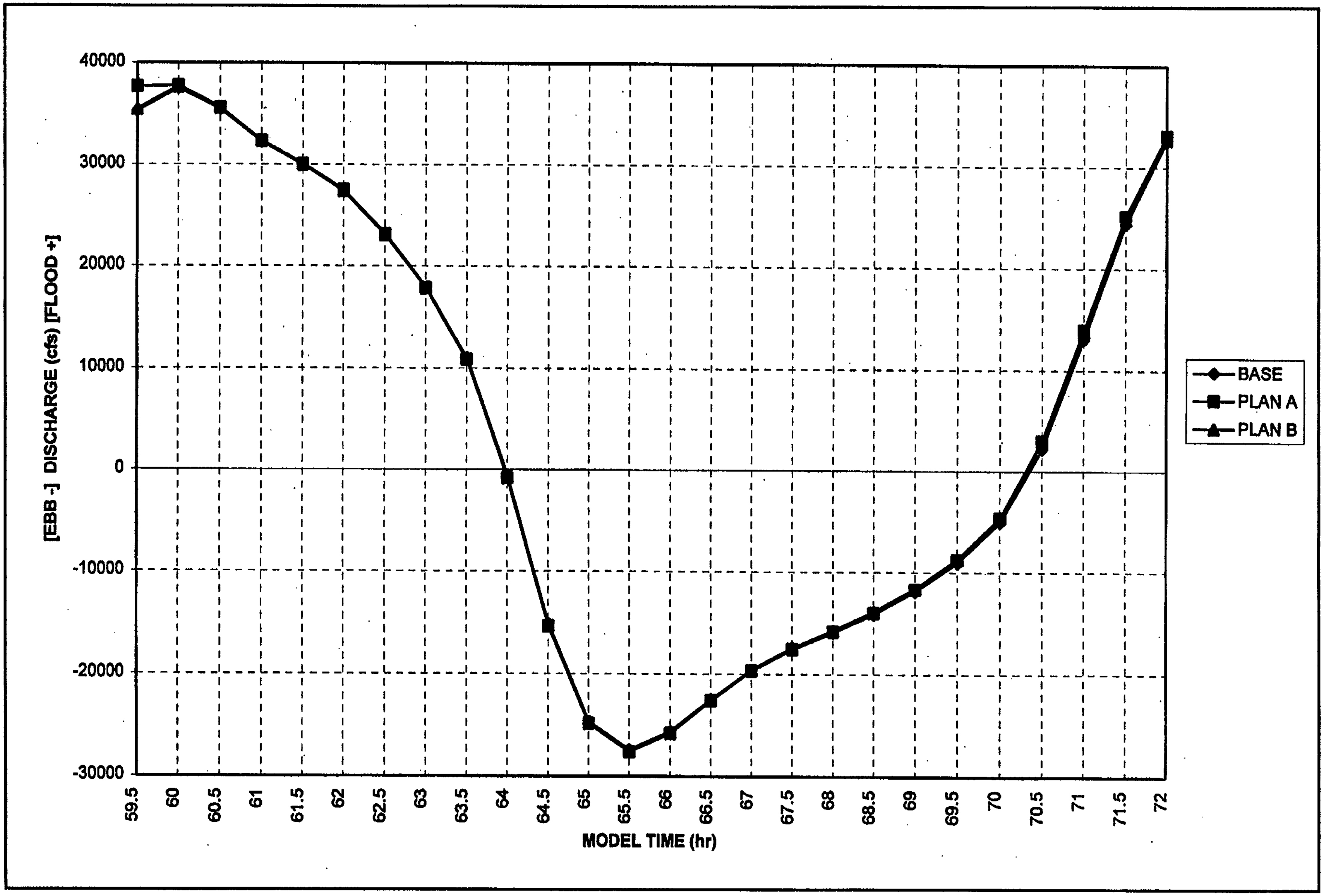

Figure A58. Water discharge at Range 24

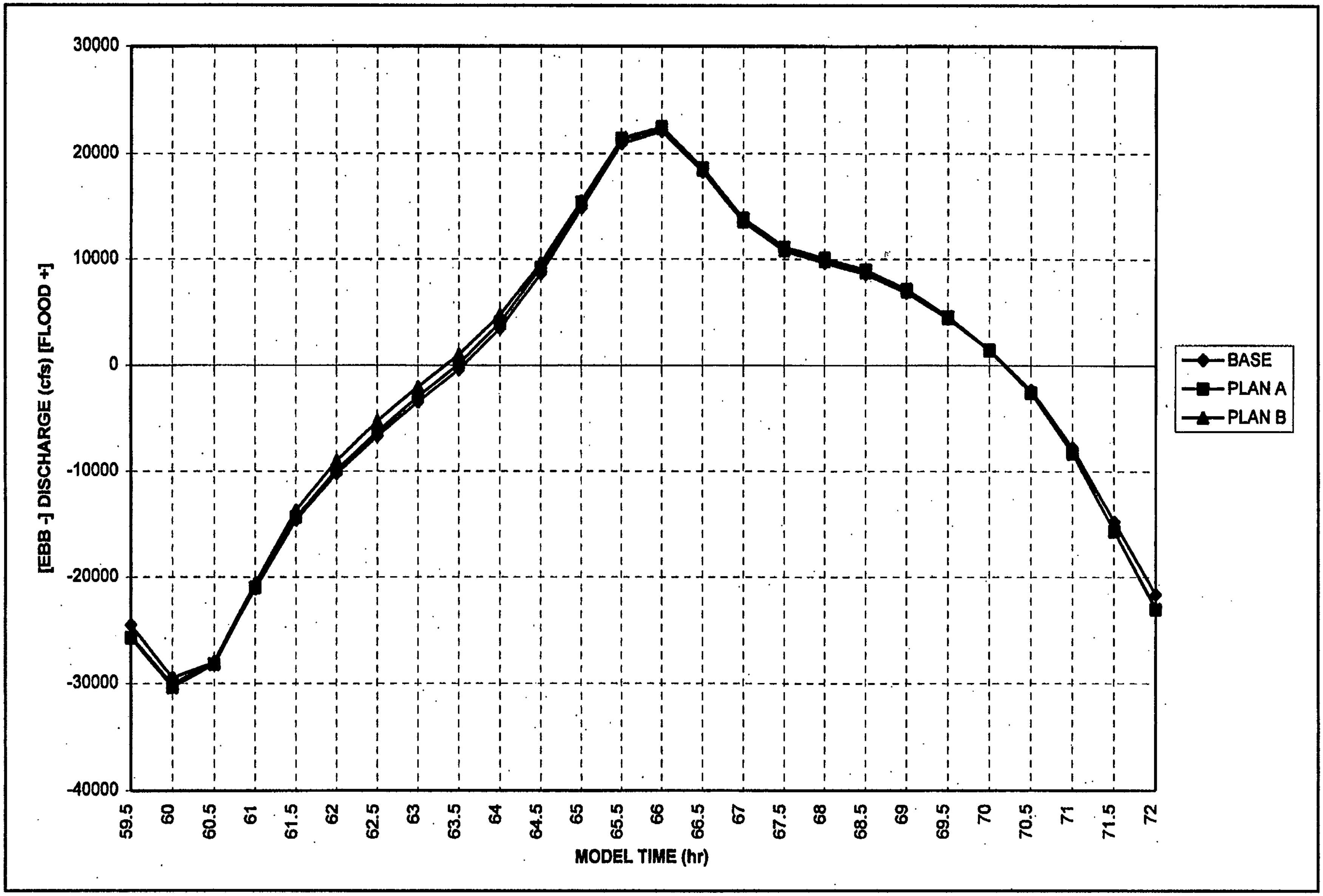

Figure A59. Water discharge at Range 35

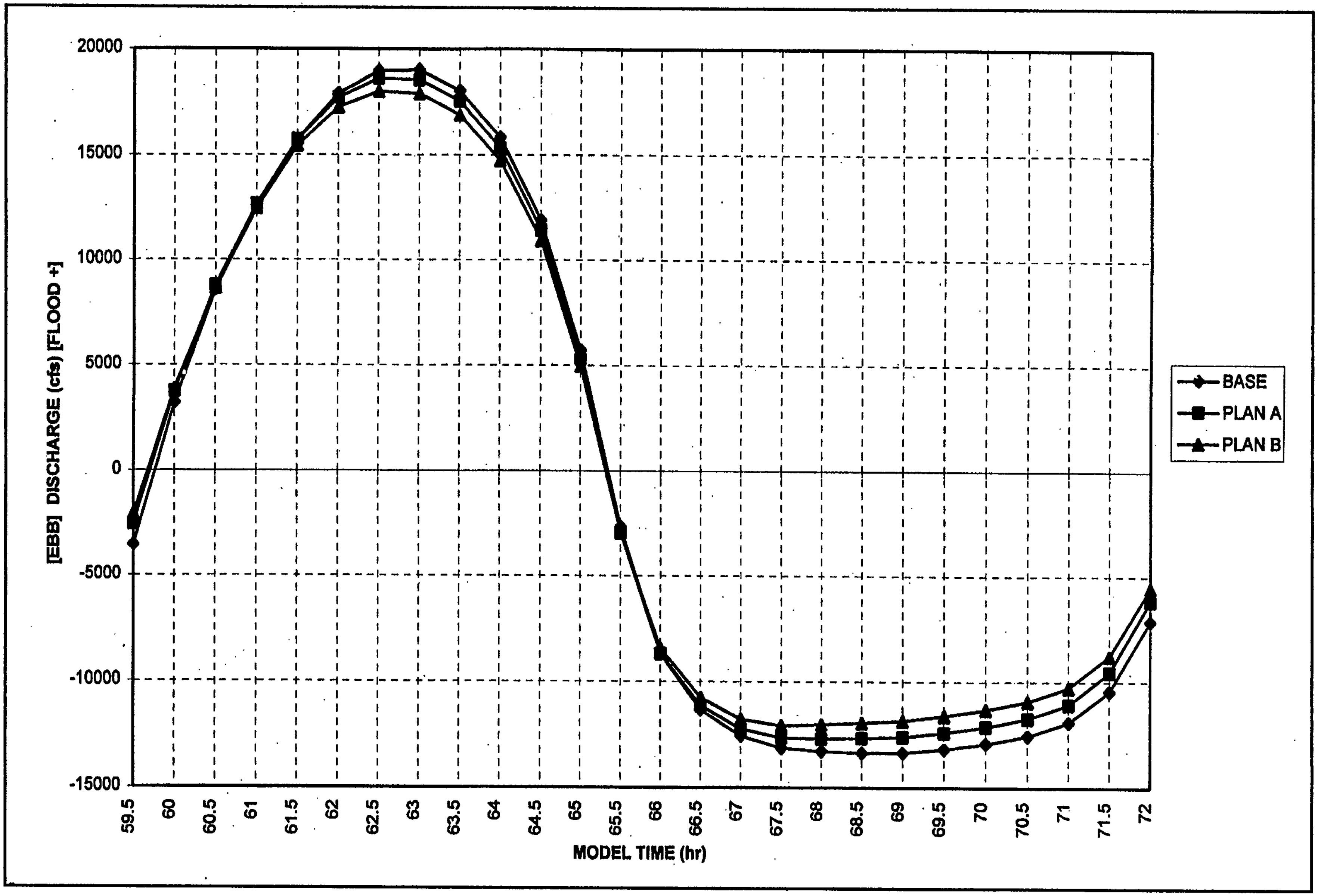

Figure A60. Water discharge at Range 36

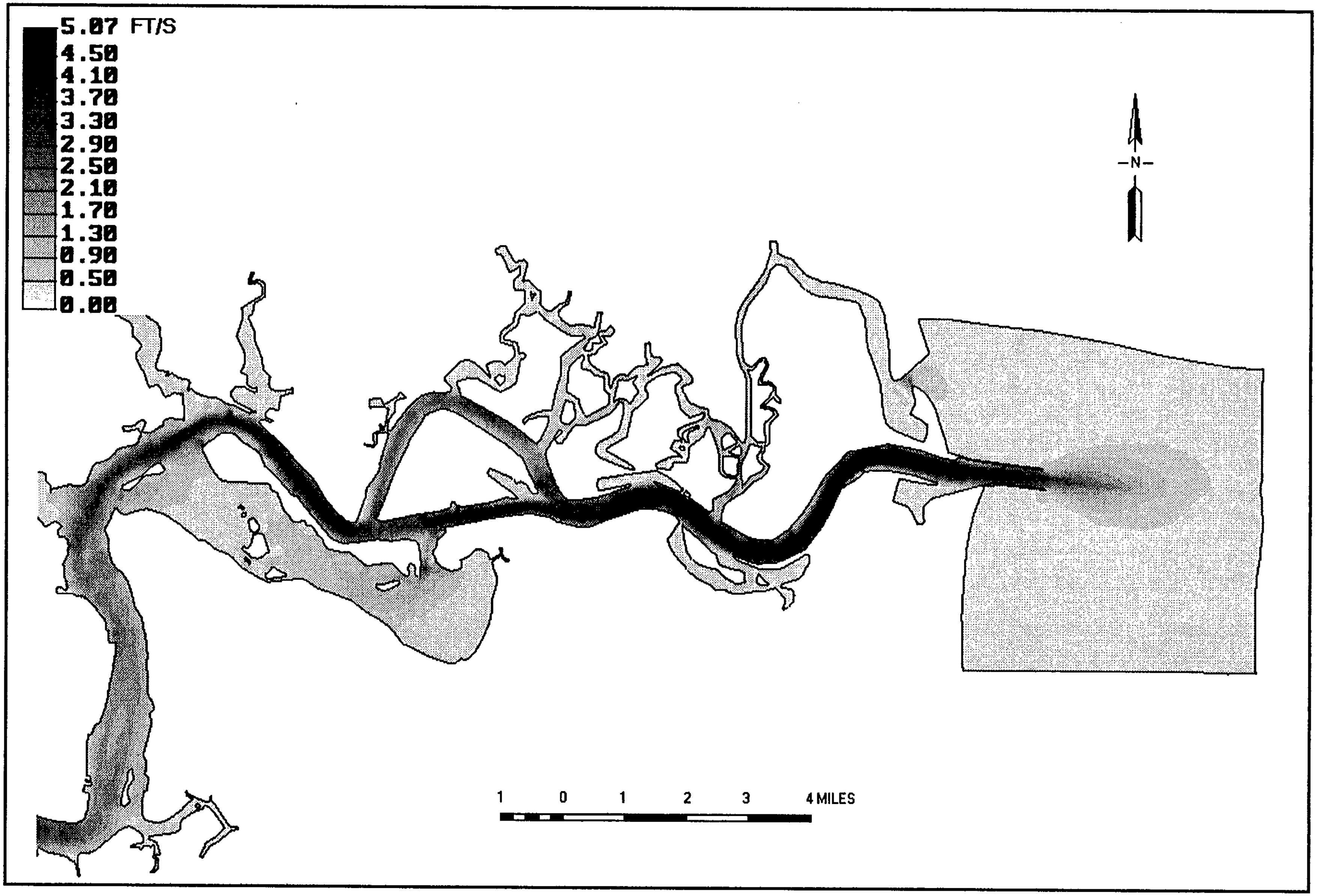

Figure A61. Ebb velocity contour map, existing conditions

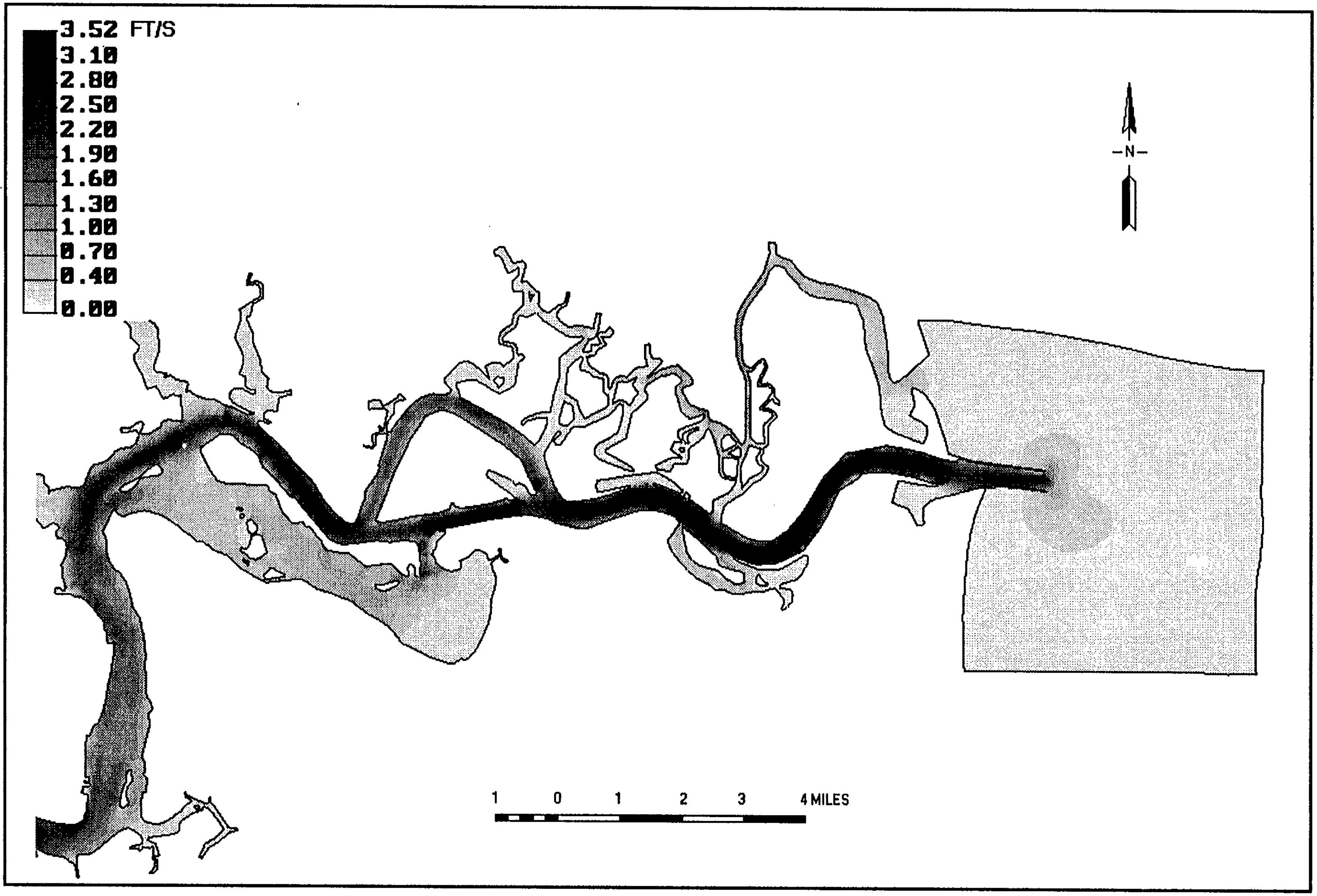

Figure A62. Flood velocity contour map, existing conditions

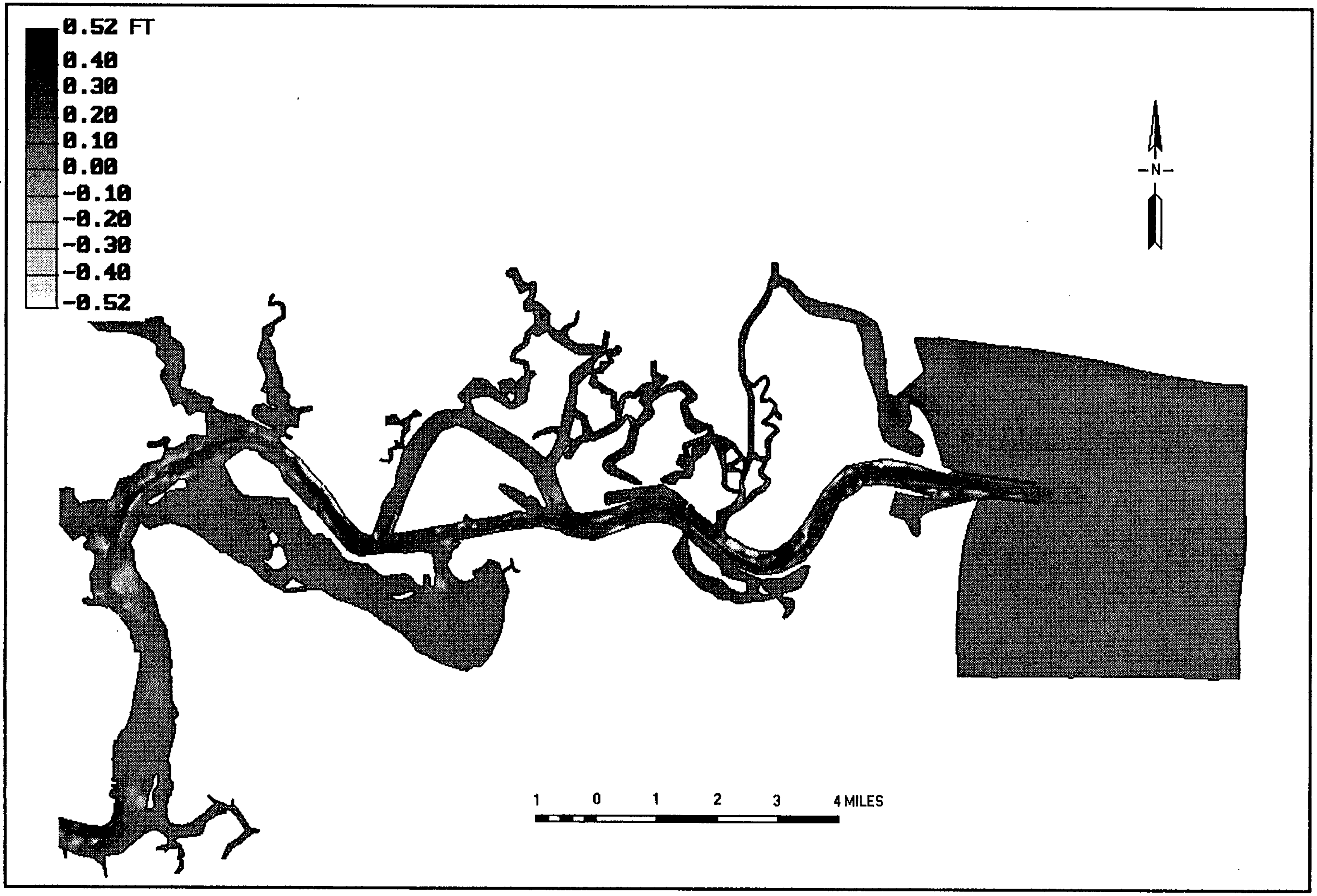

Figure A63. Contour of bed change (fine sand), existing conditions

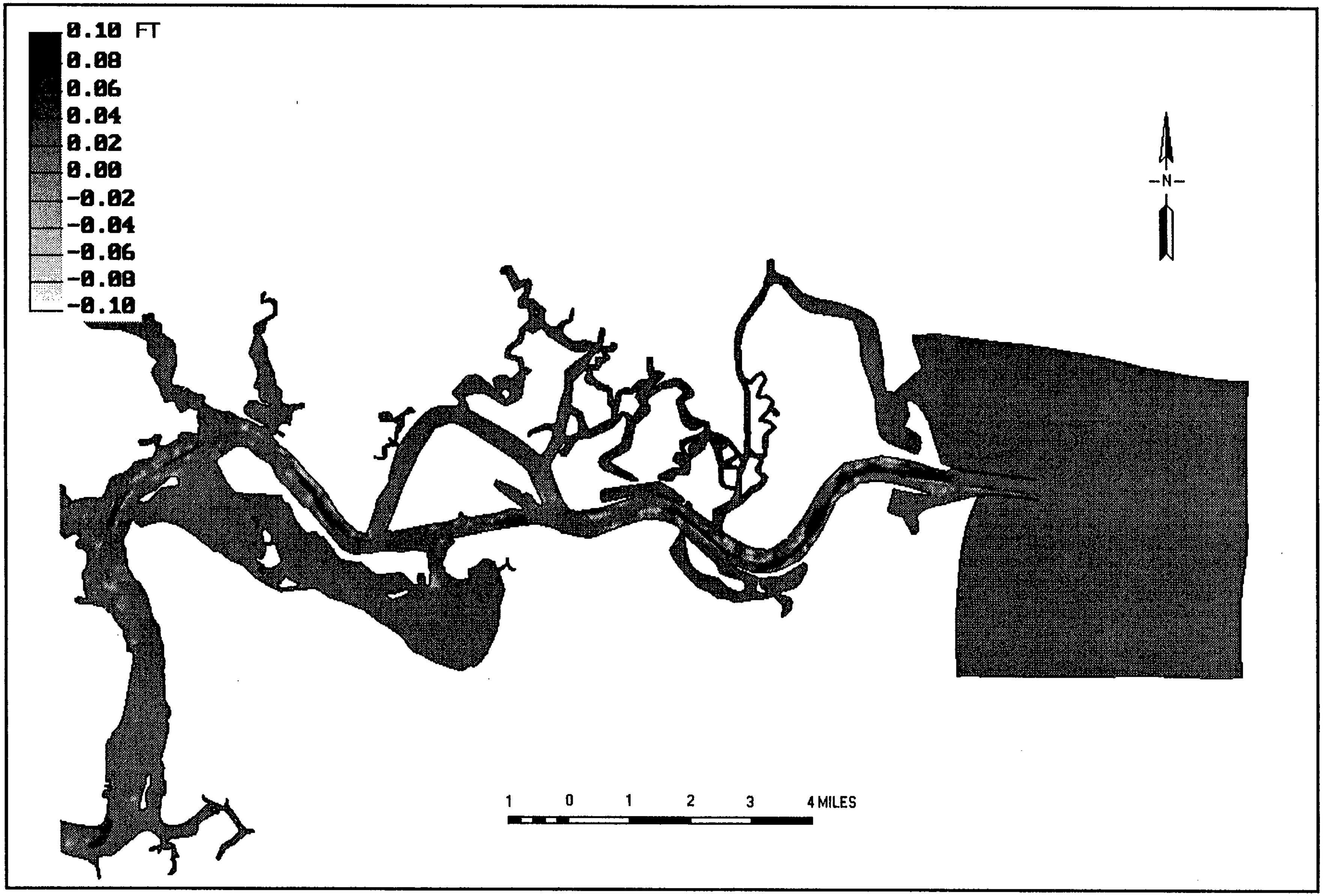

Figure A64. Contour map of bed change (medium sand), existing conditions

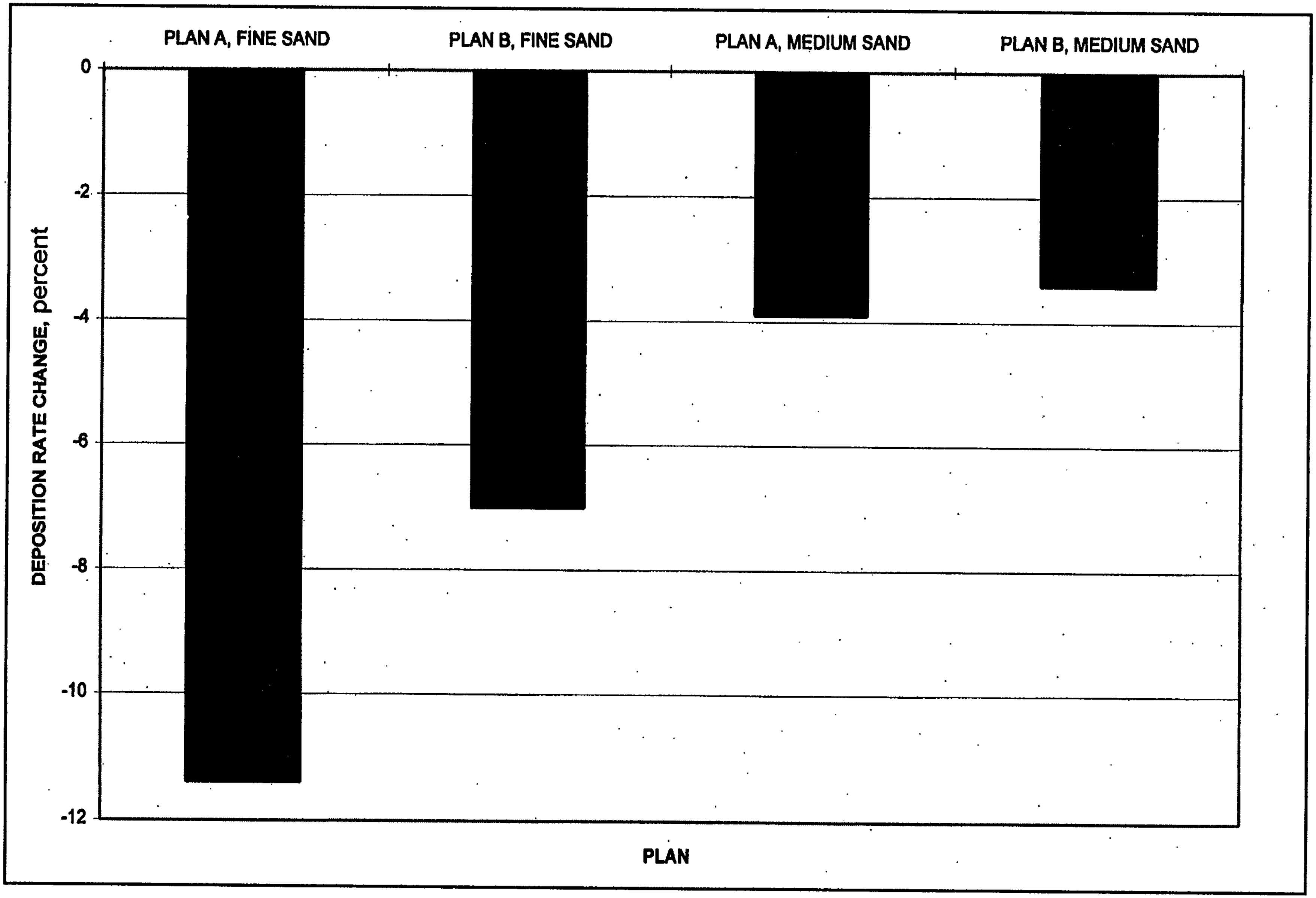

Figure A65. Change in deposition rate, St. Johns Bar Cut Range (west section) to Pilot Town Cut Range

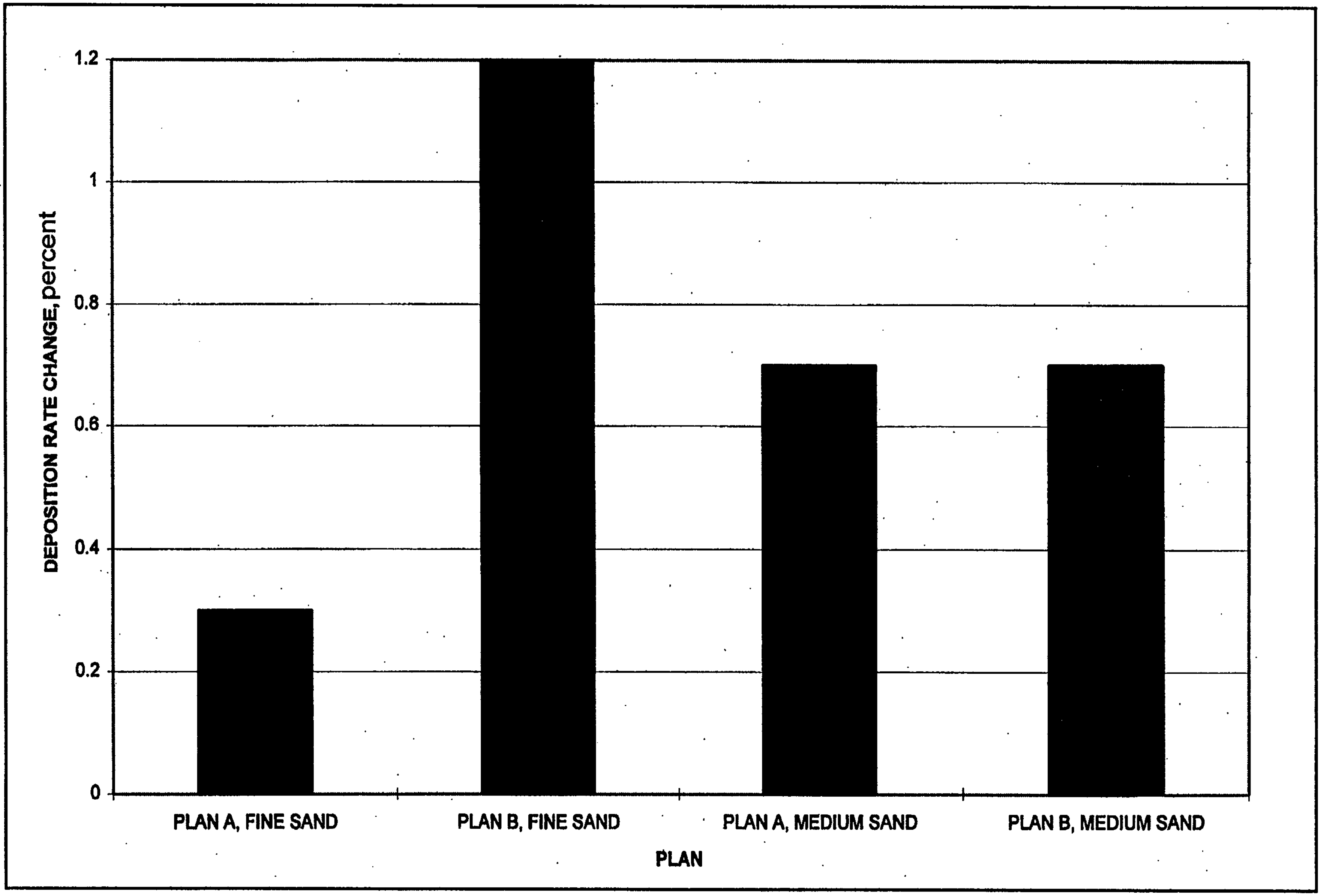

Figure 66. Change in deposition rate, Mayport Cut Range to Sherman Cut Range

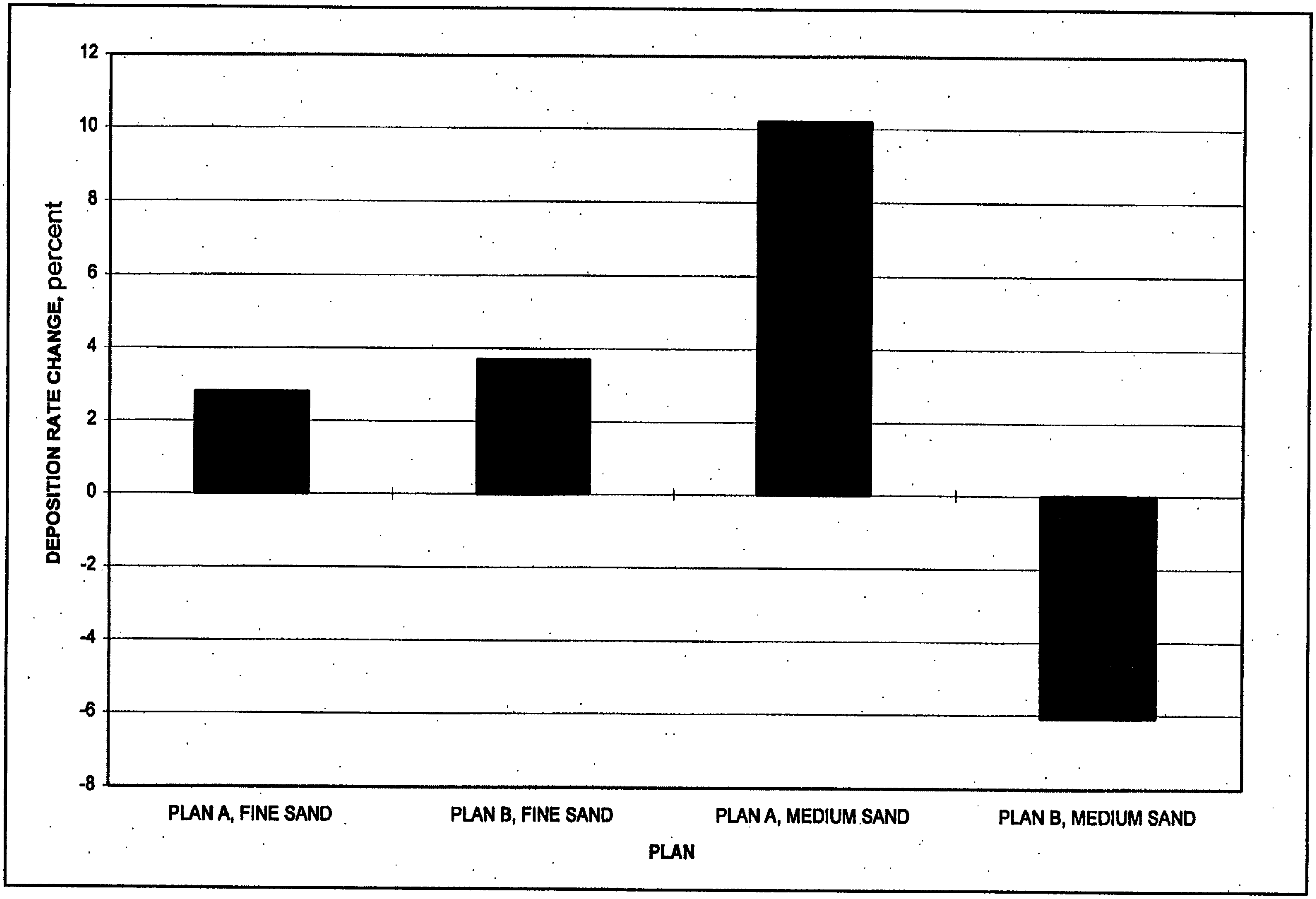

Figure A67. Change in deposition rate, Mile Point Lower Range and turn

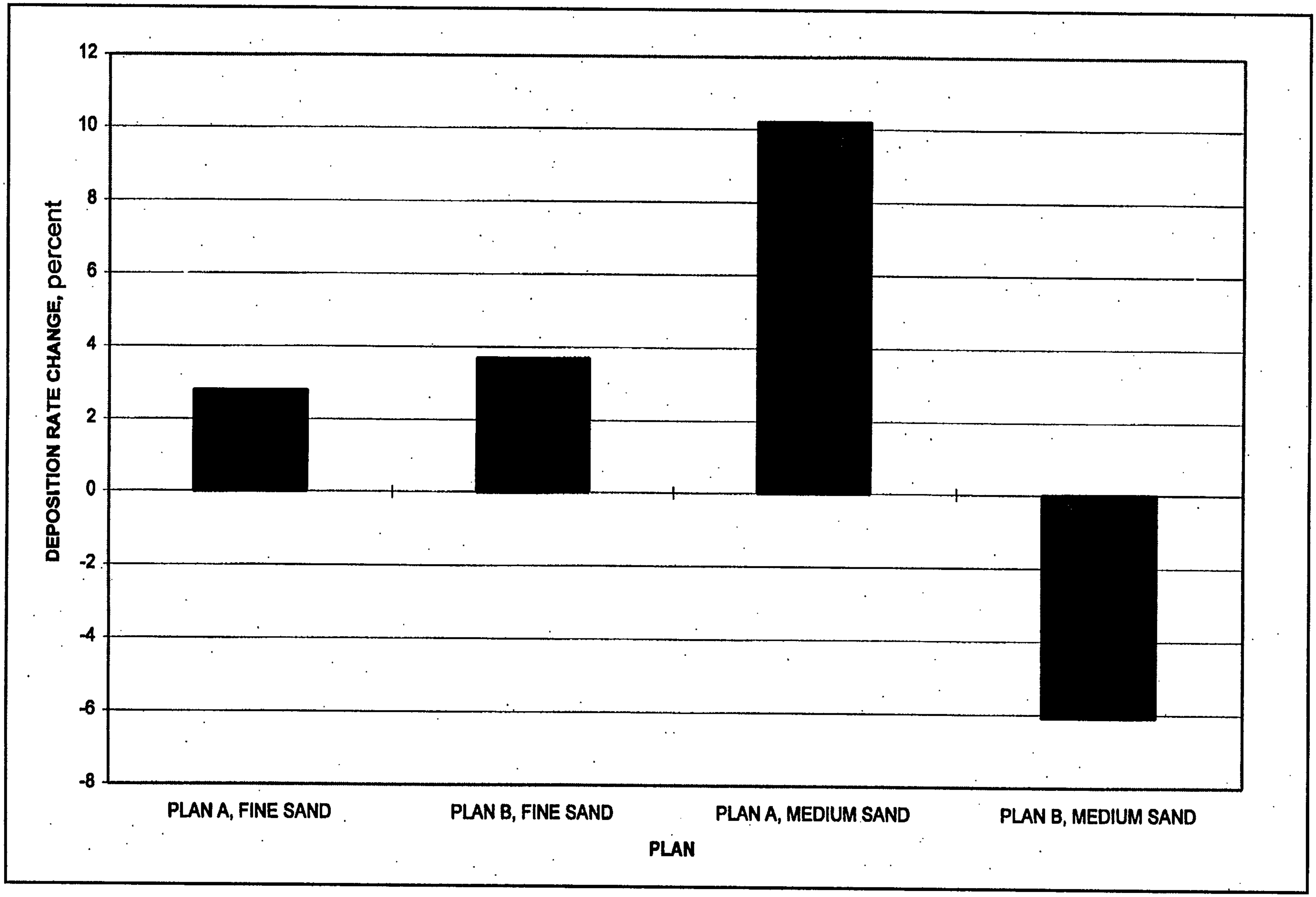

Figure A68. Change in deposition rate, Training Wall Reach

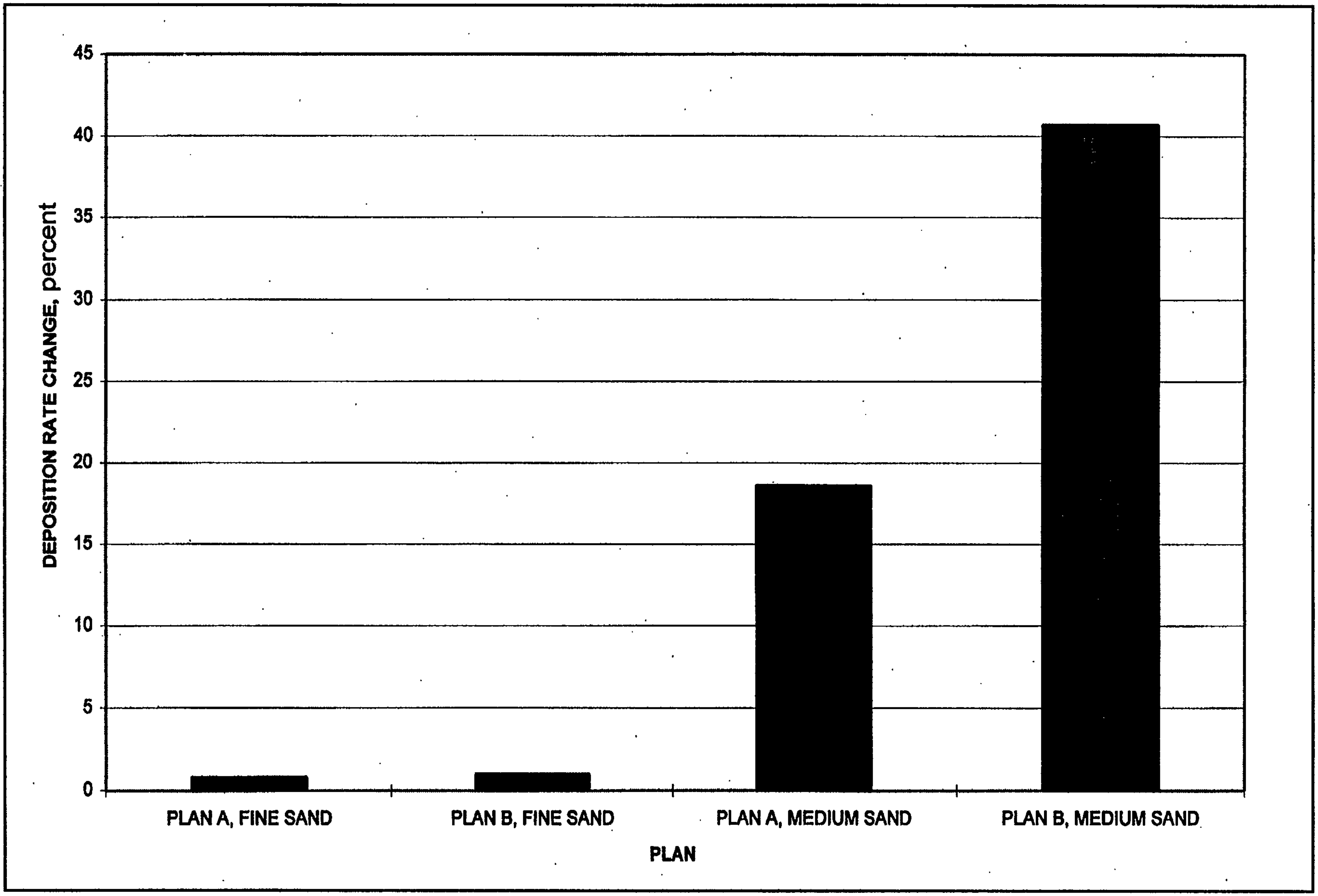

Figure A69. Change in deposition rate, Short Cut Turn

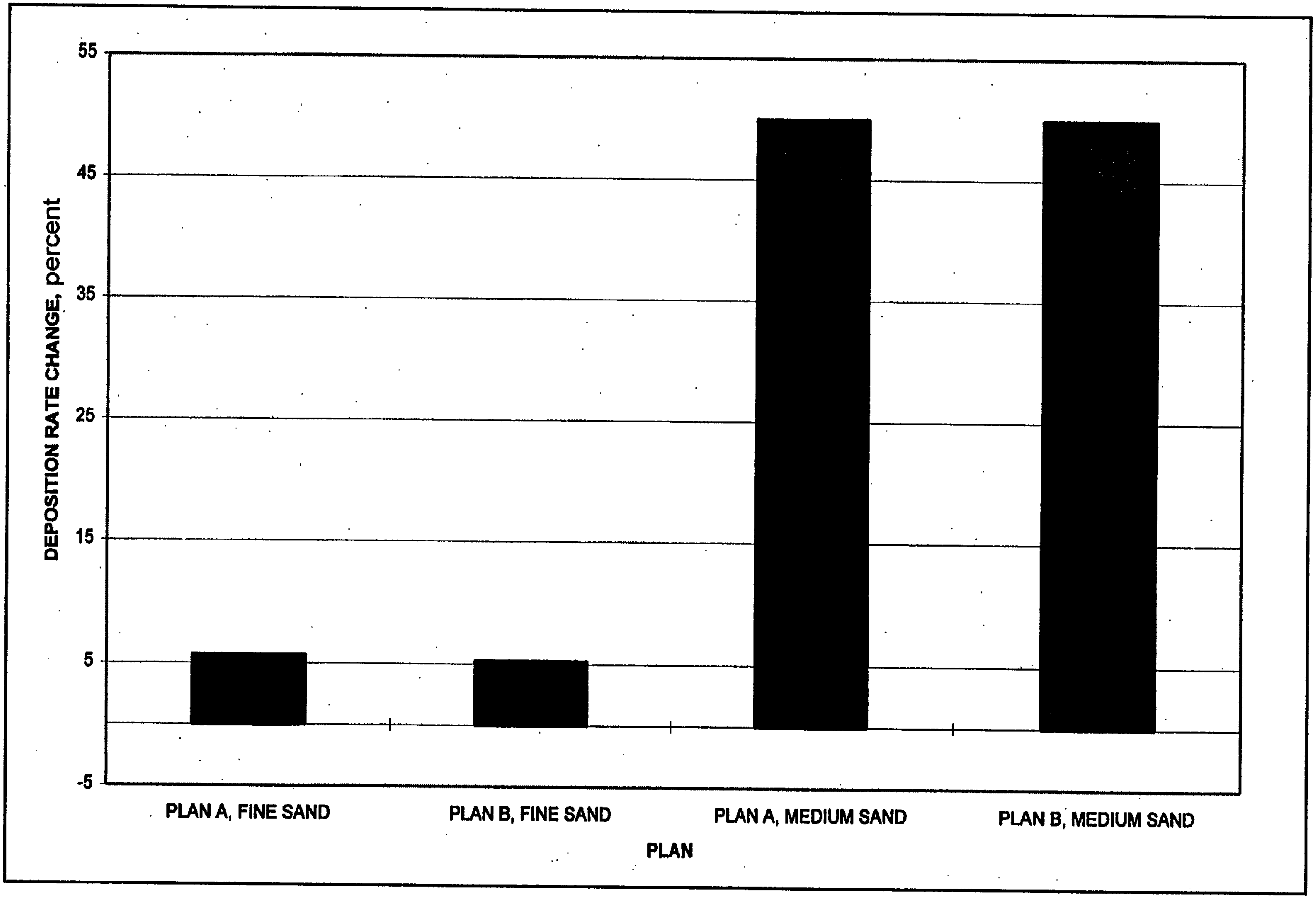

Figure A70. Change in deposition rate, White Shells Cut Range

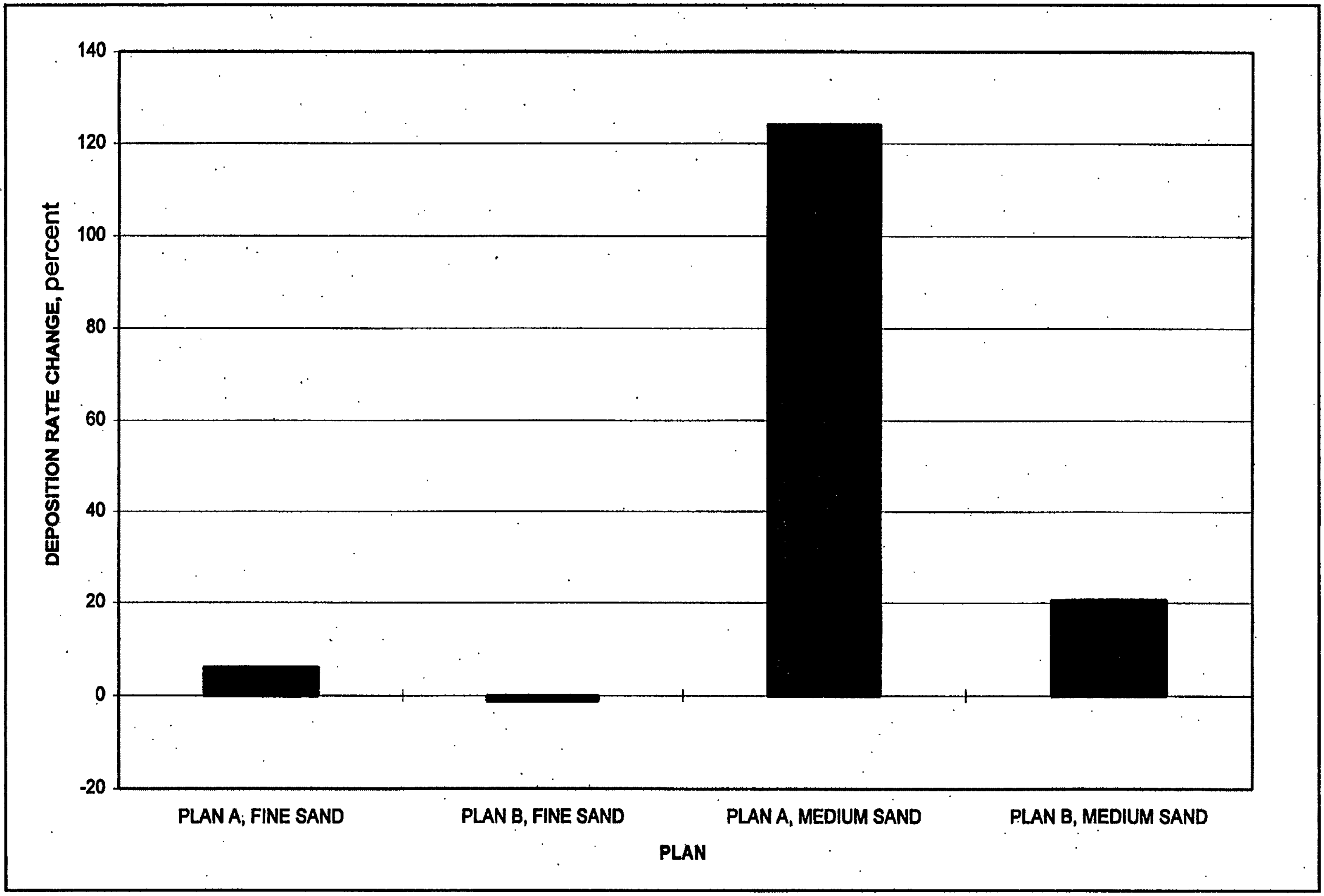

Figure A71. Change in deposition rate, St. Johns Bluff Reach

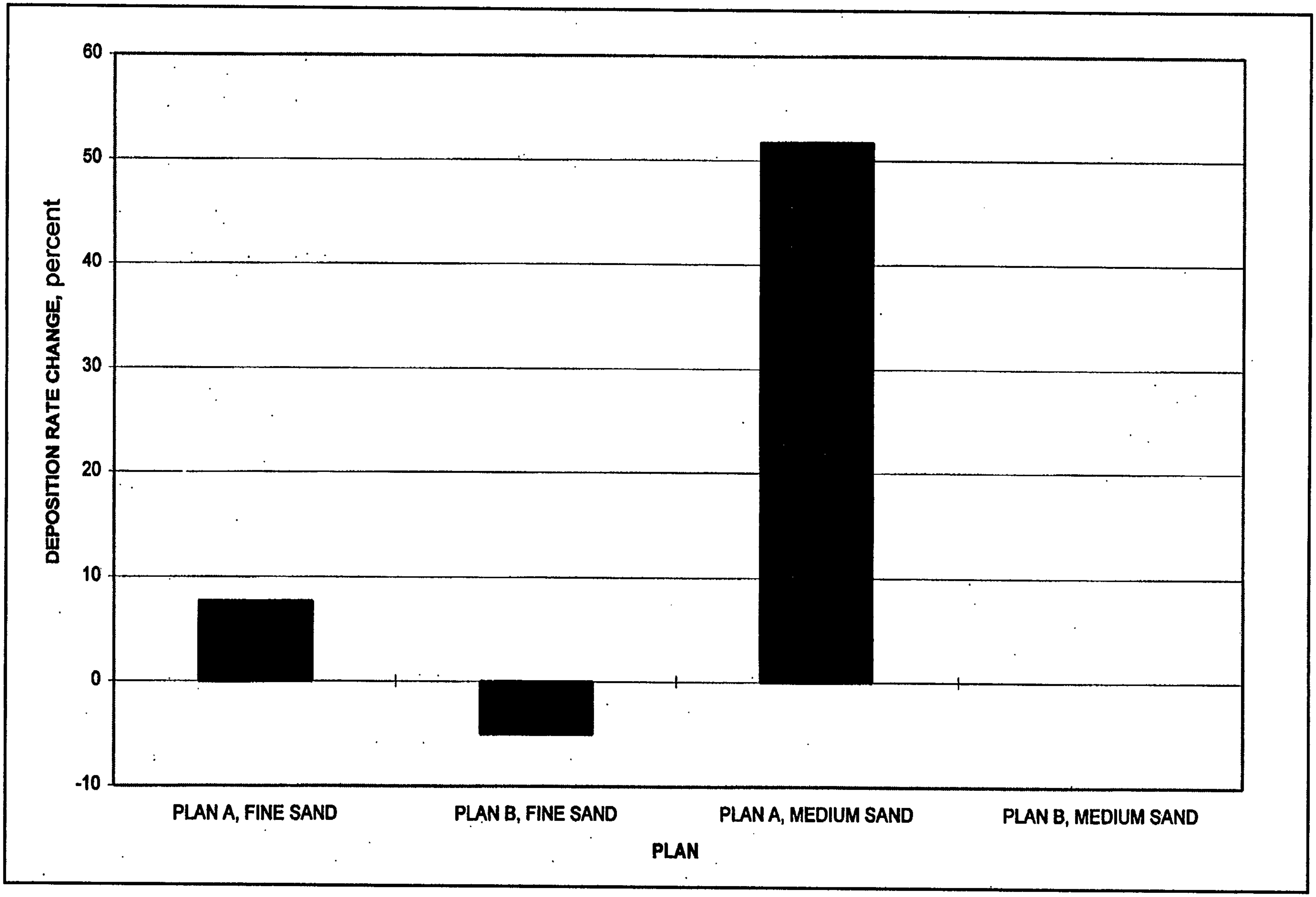

Figure A72. Change in deposition rate, Fulton-Dames Point Cutoff Range (East)

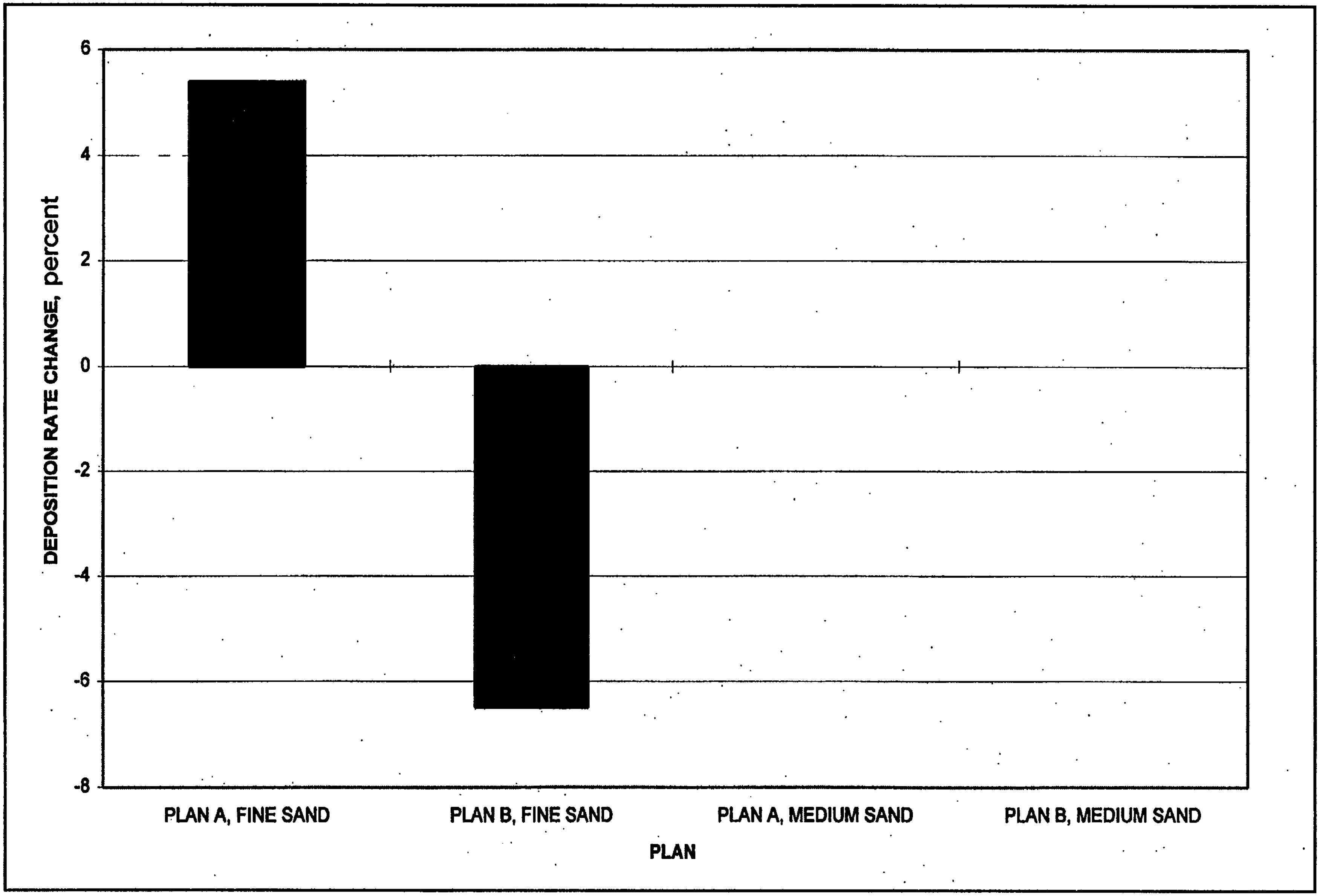

Figure A73. Change in deposition rate, Fulton-Dames Point Cutoff Range (Middle)

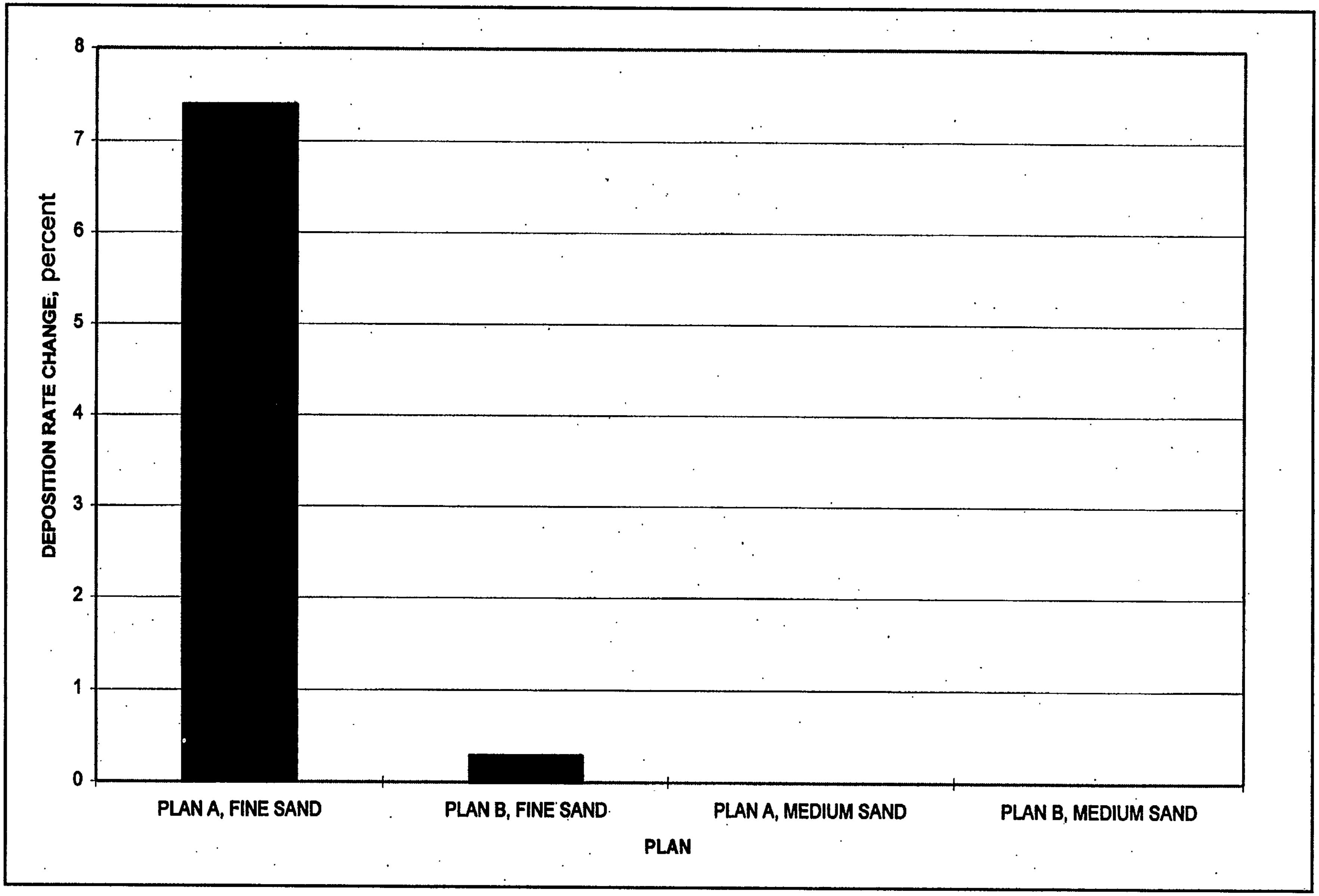

Figure A74. Change in deposition rate, Fulton-Dames Point Cutoff Range (West)

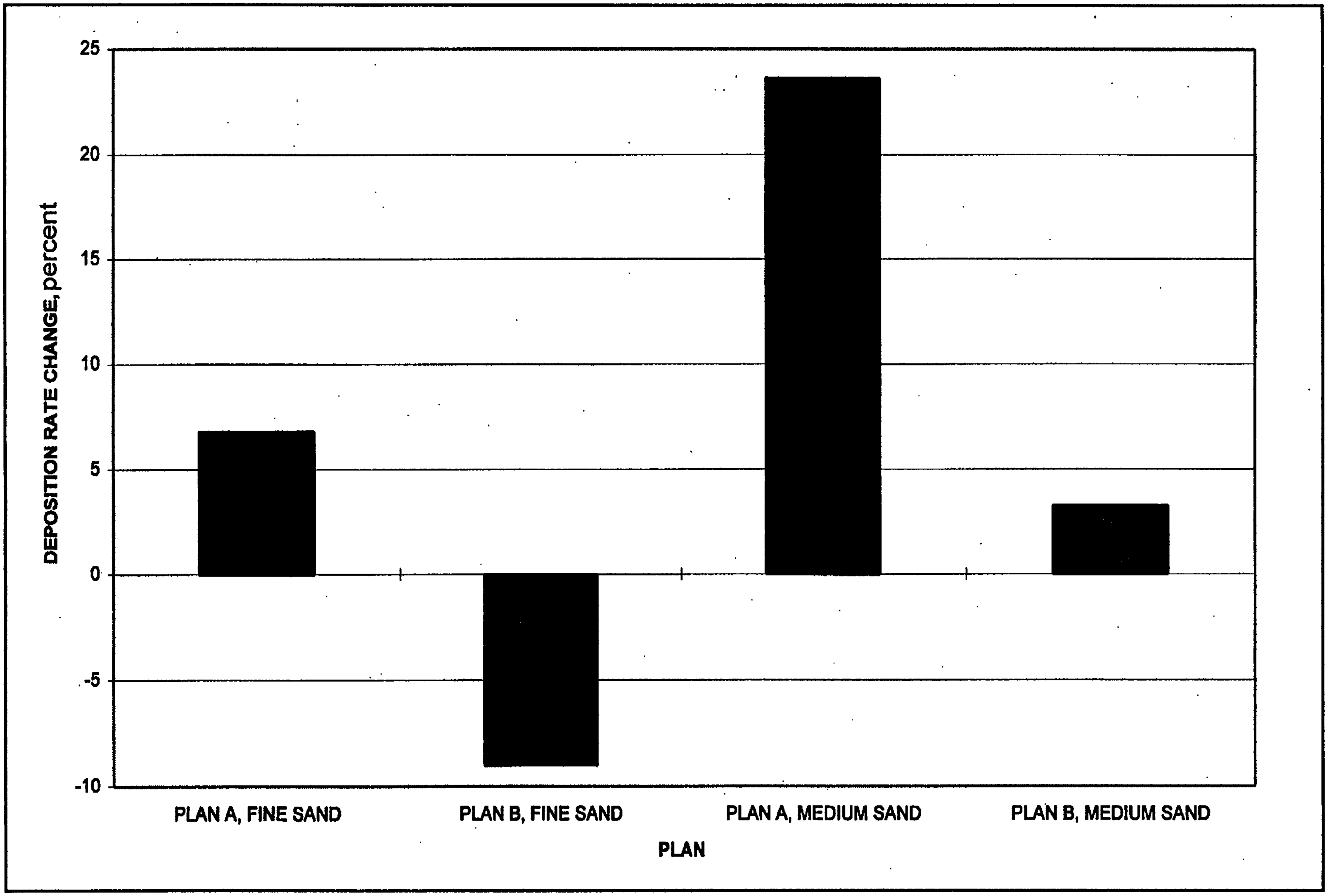

Figure A75. Change in deposition rate, Dames Point Turn to Brills Cut Range

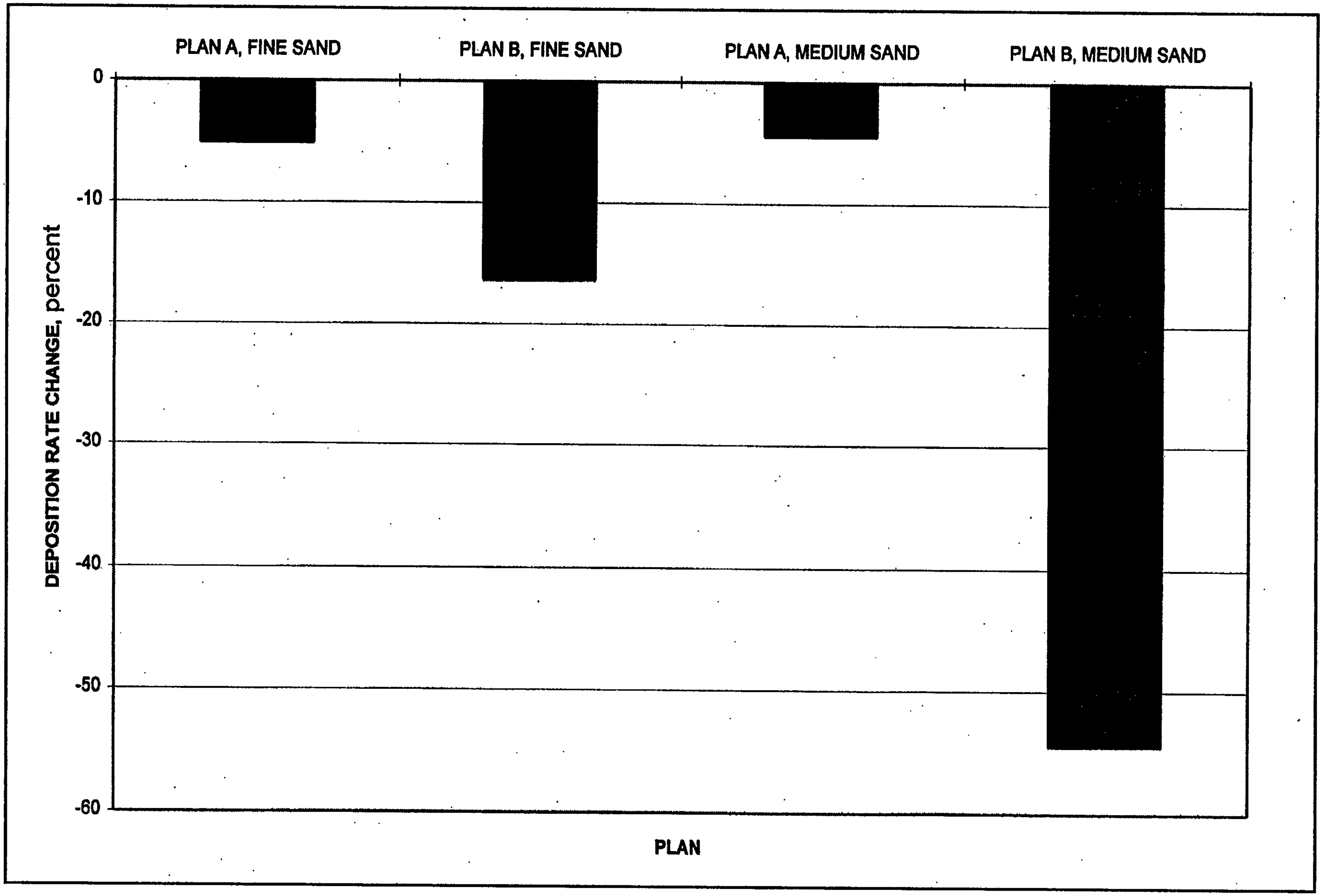

Figure A76. Change in deposition rate, Brills Cut Range (West) to Broward Point Turn

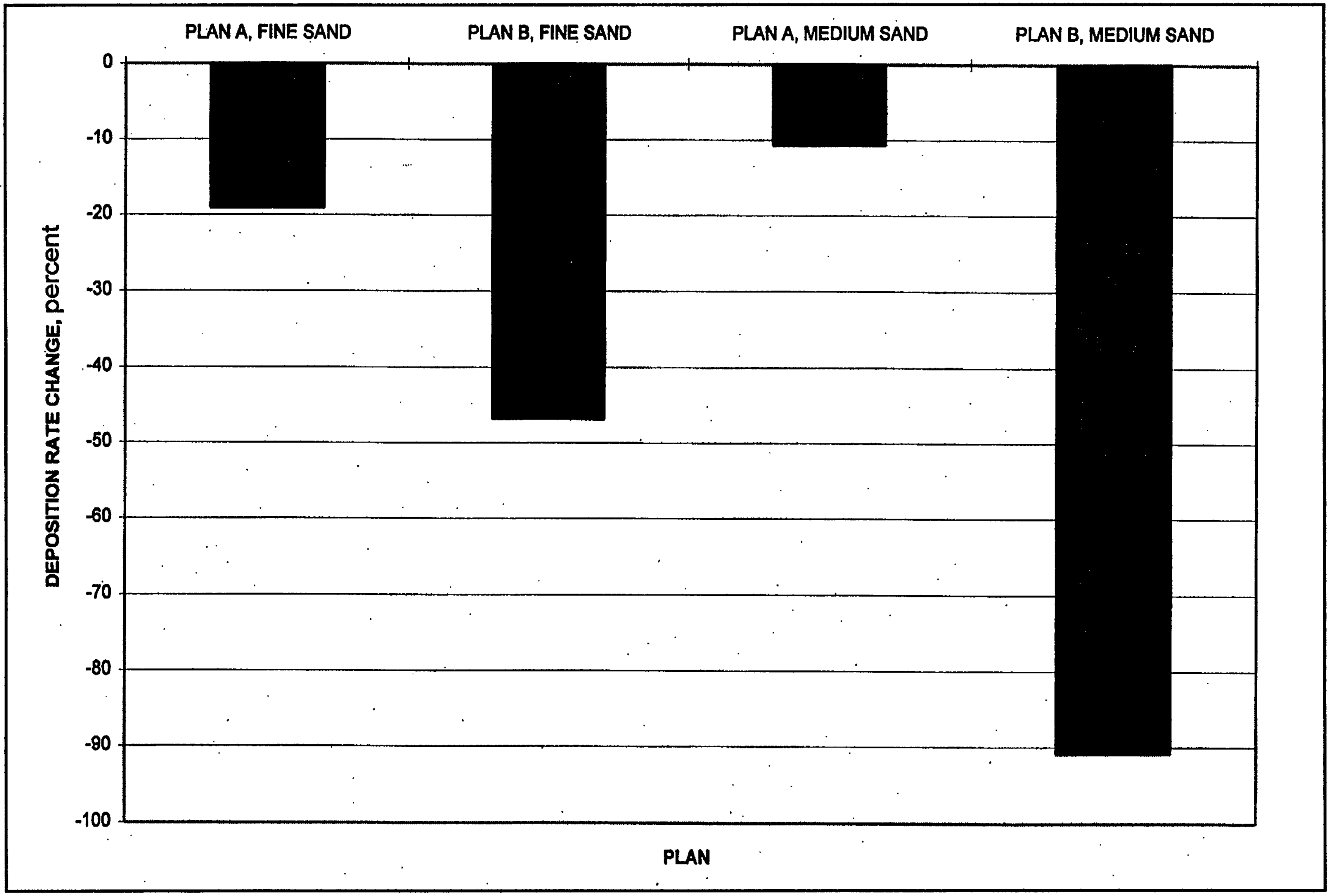

Figure A77. Change in deposition rate, Broward Point Turn (West) to Drummond Creek Range (North)

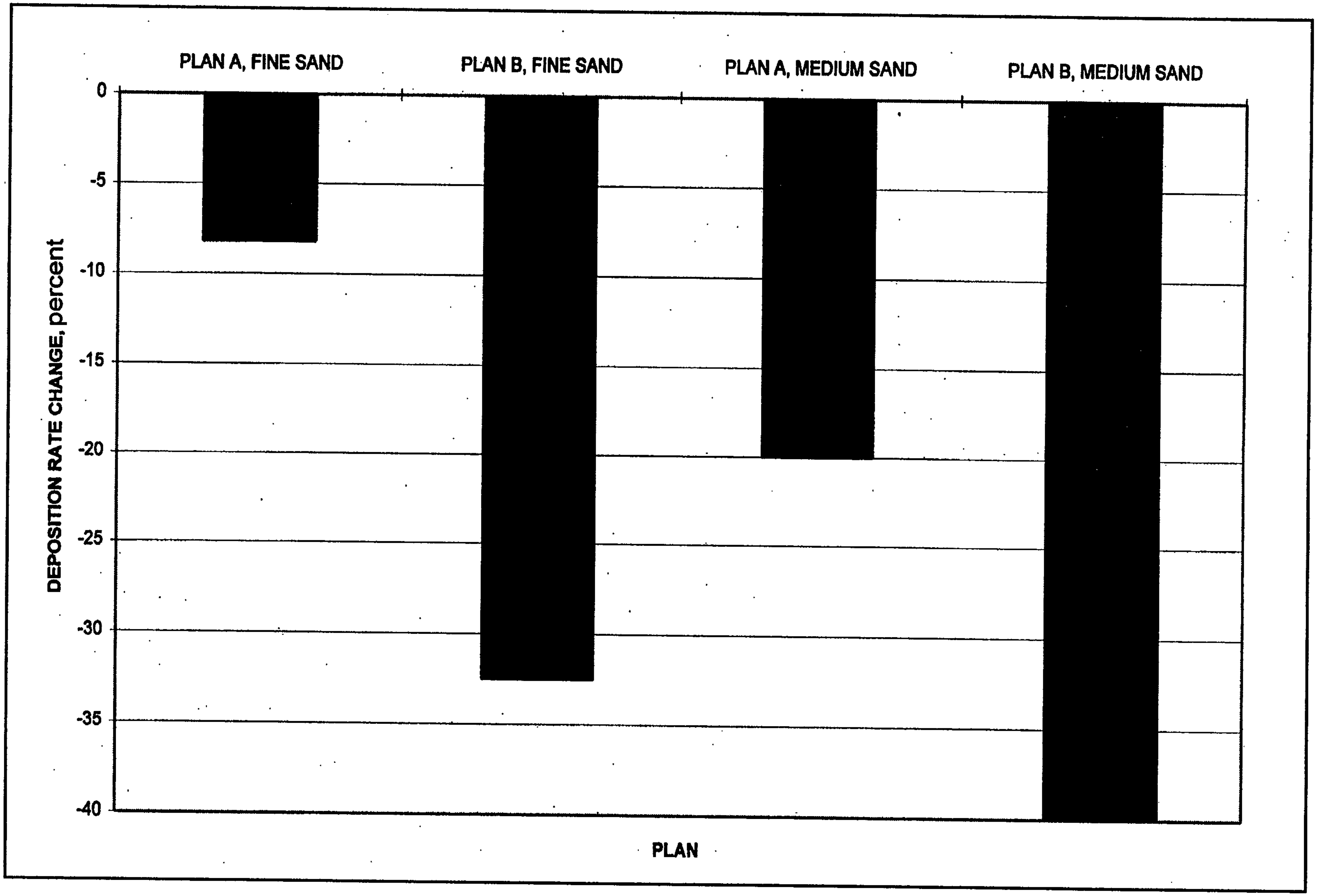

Figure A78. Change in deposition rate, Drummond Creek Range

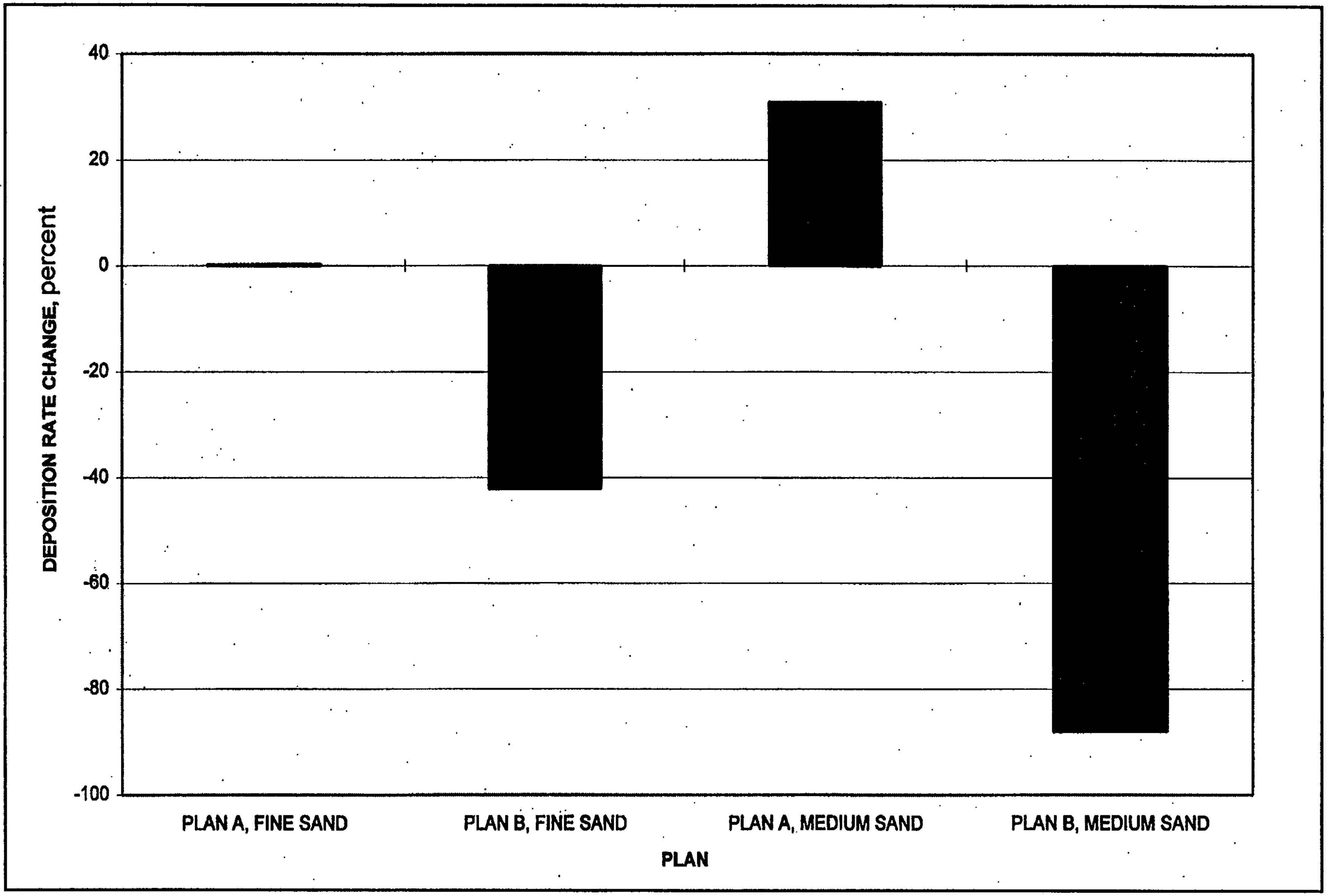

Figure A79. Change in deposition rate, Trout River Cut Range (North)

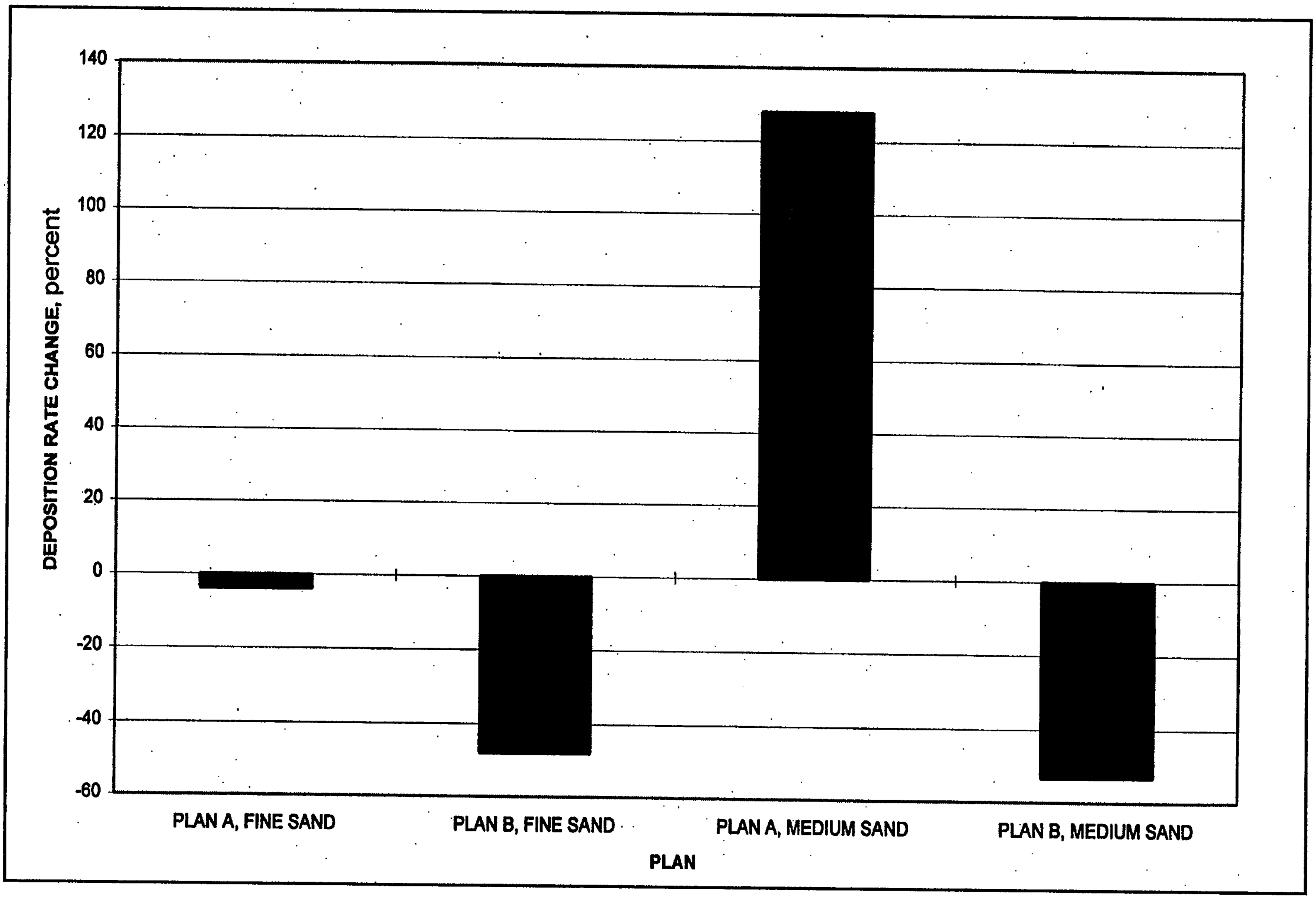

Figure A80. Change in deposition rate, Trout River Cut Range to Chaseville Turn

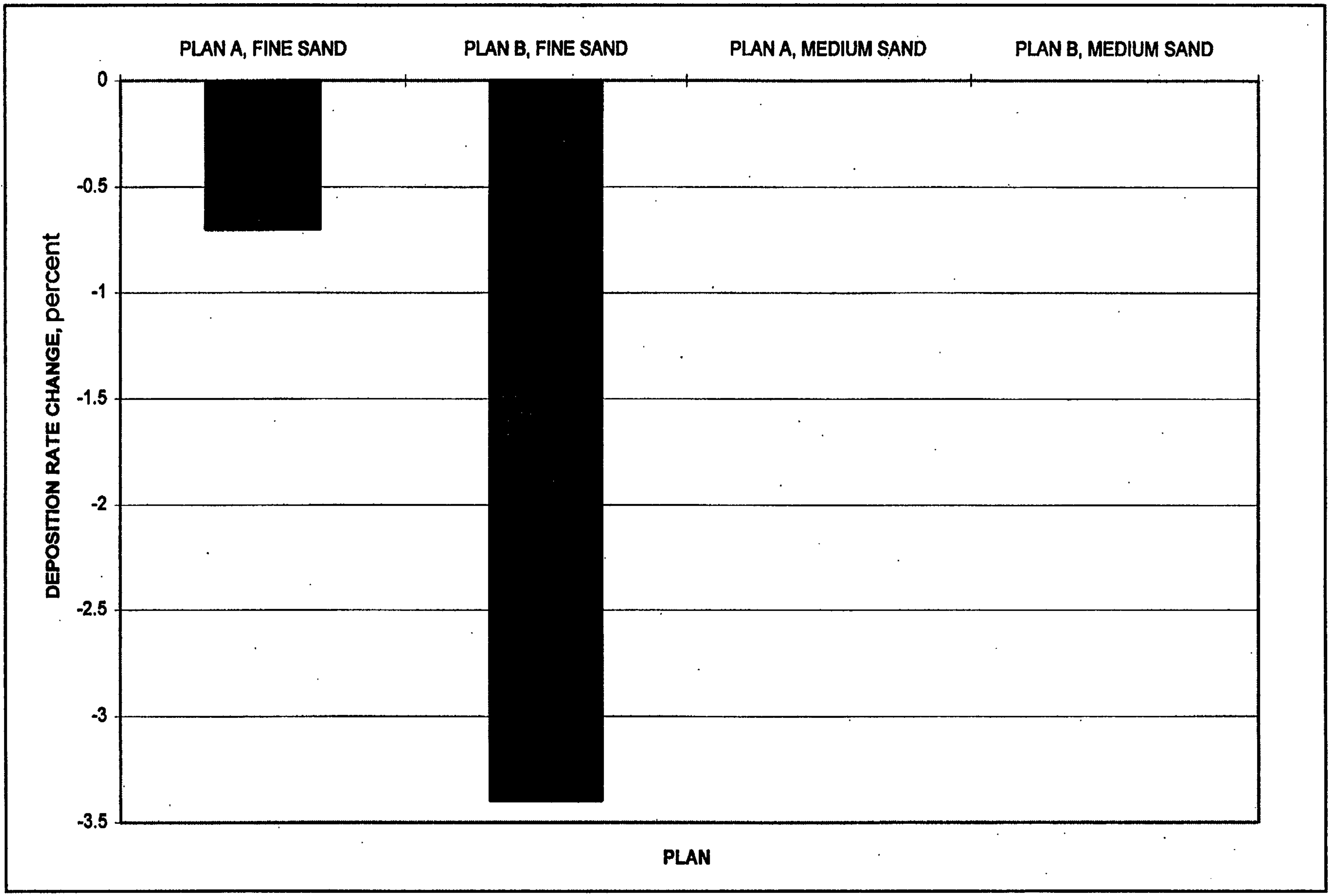

Figure A81. Change in deposition rate, Long Branch Range

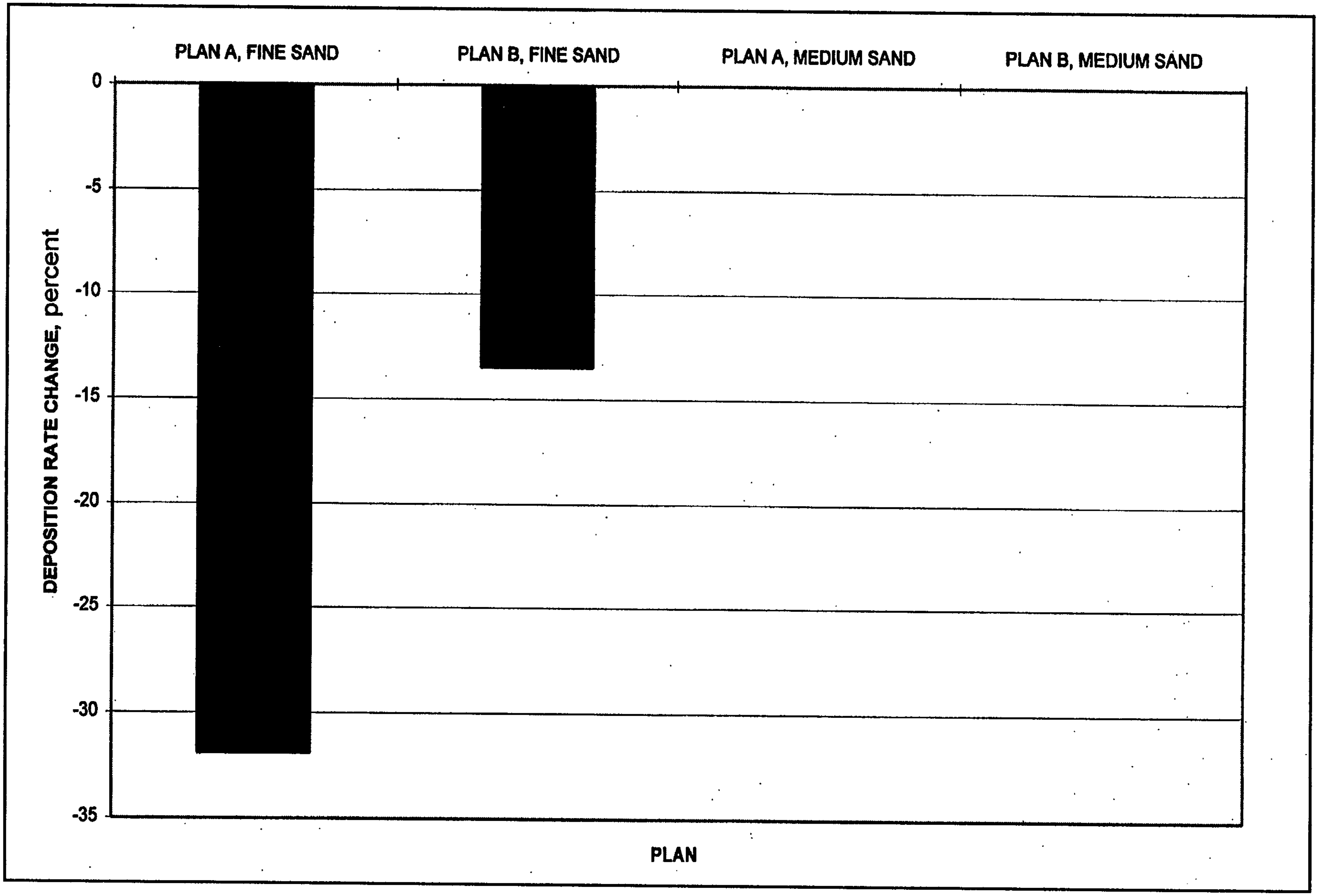

Figure A82. Change in deposition rate, Terminal Channel

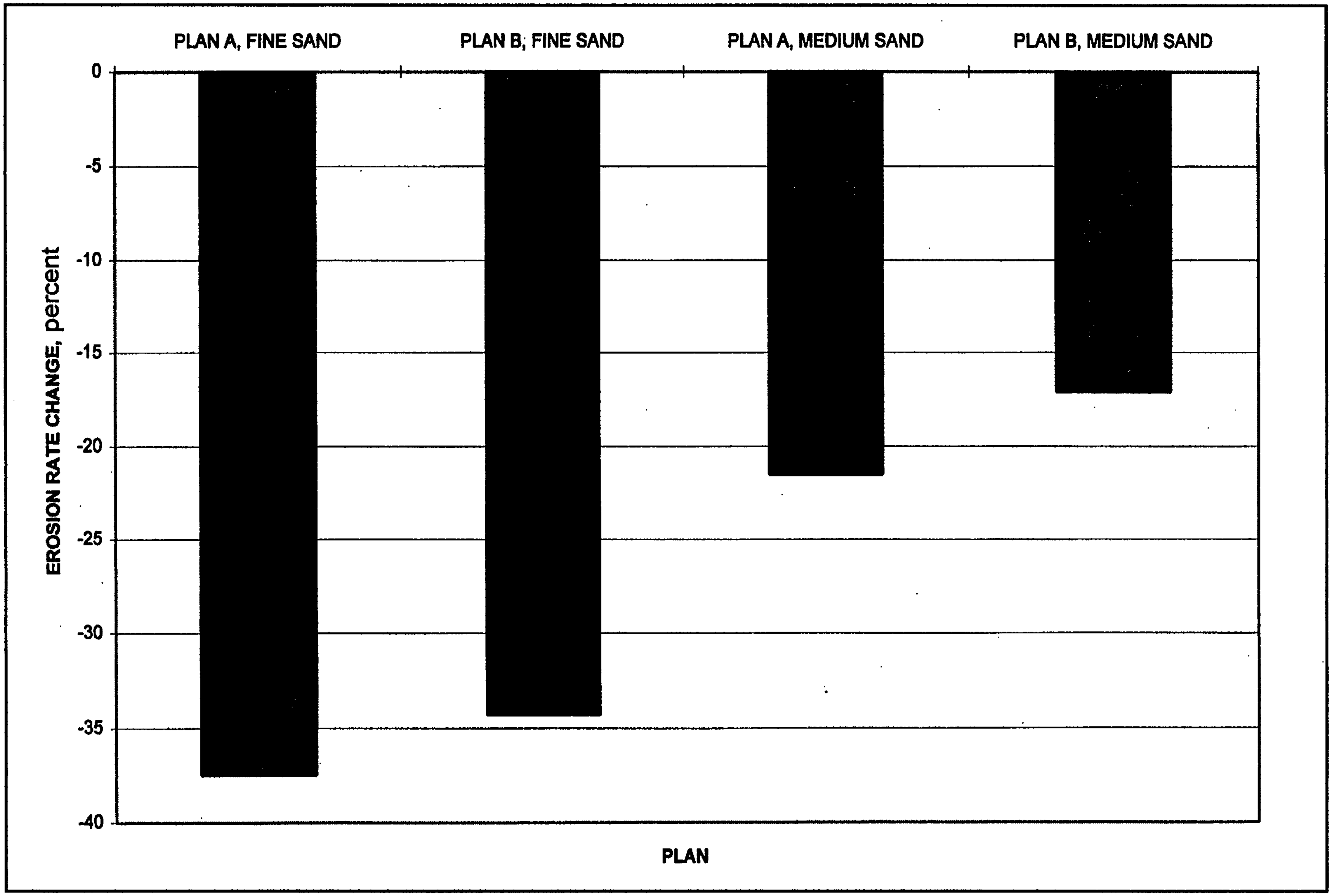

Figure A83. Change in deposition rate, St. Johns Bar Cut Range, West Section (Northern Coastline)

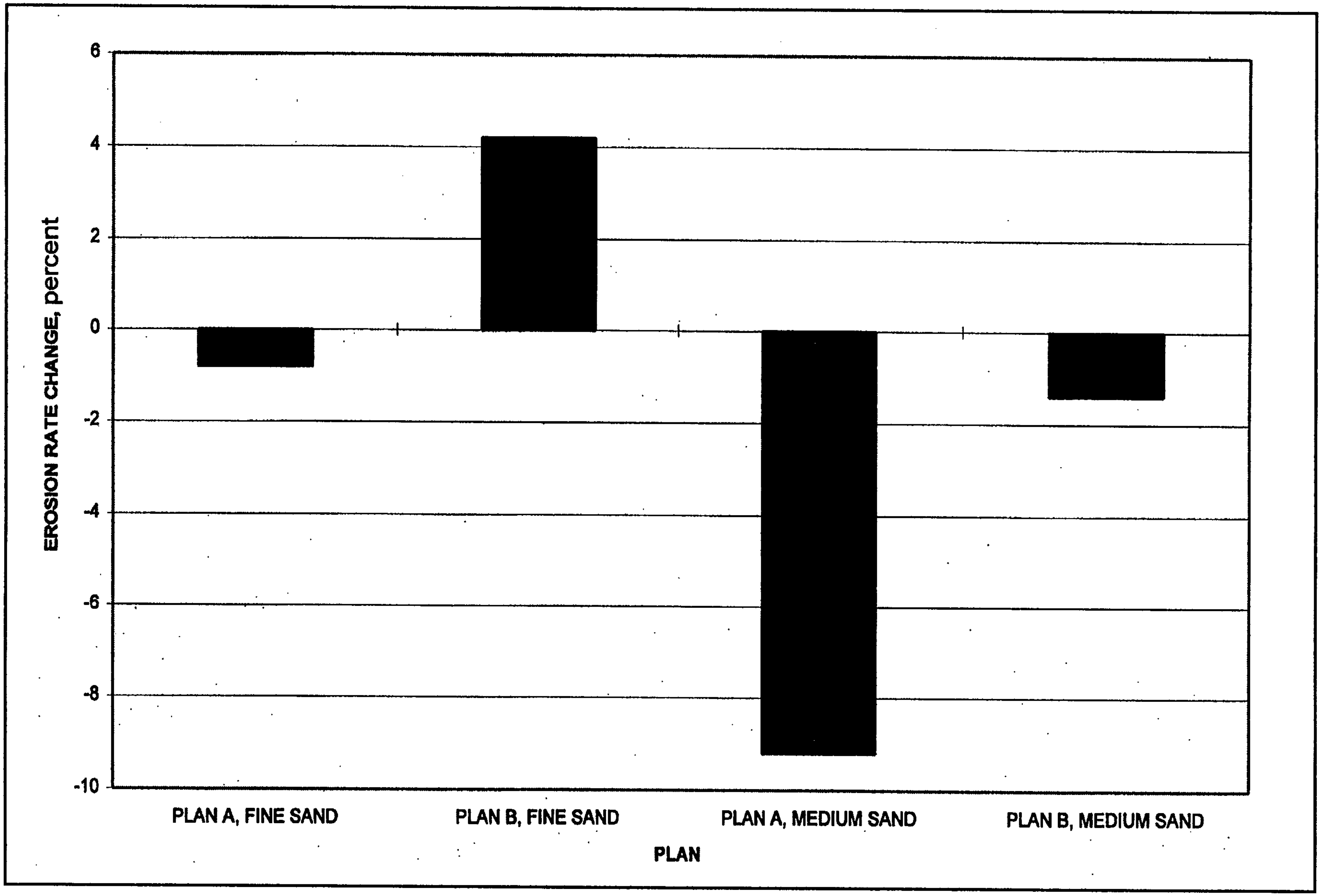

Figure A84. Change in deposition rate, Training Wall Reach (Northern Coastline)

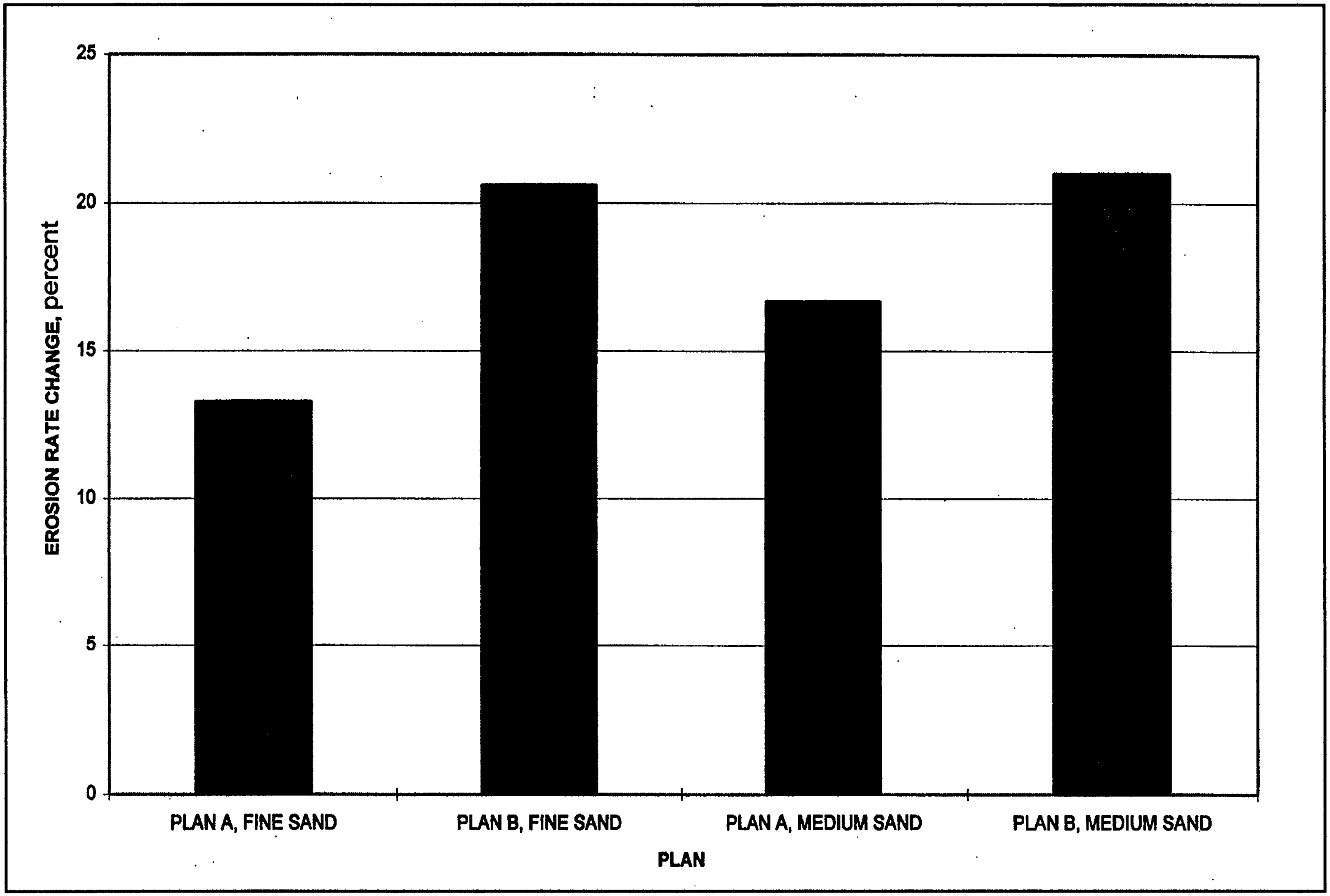

Figure A85. Change in deposition rate, White Shells Cut Range (Southern Coastline)

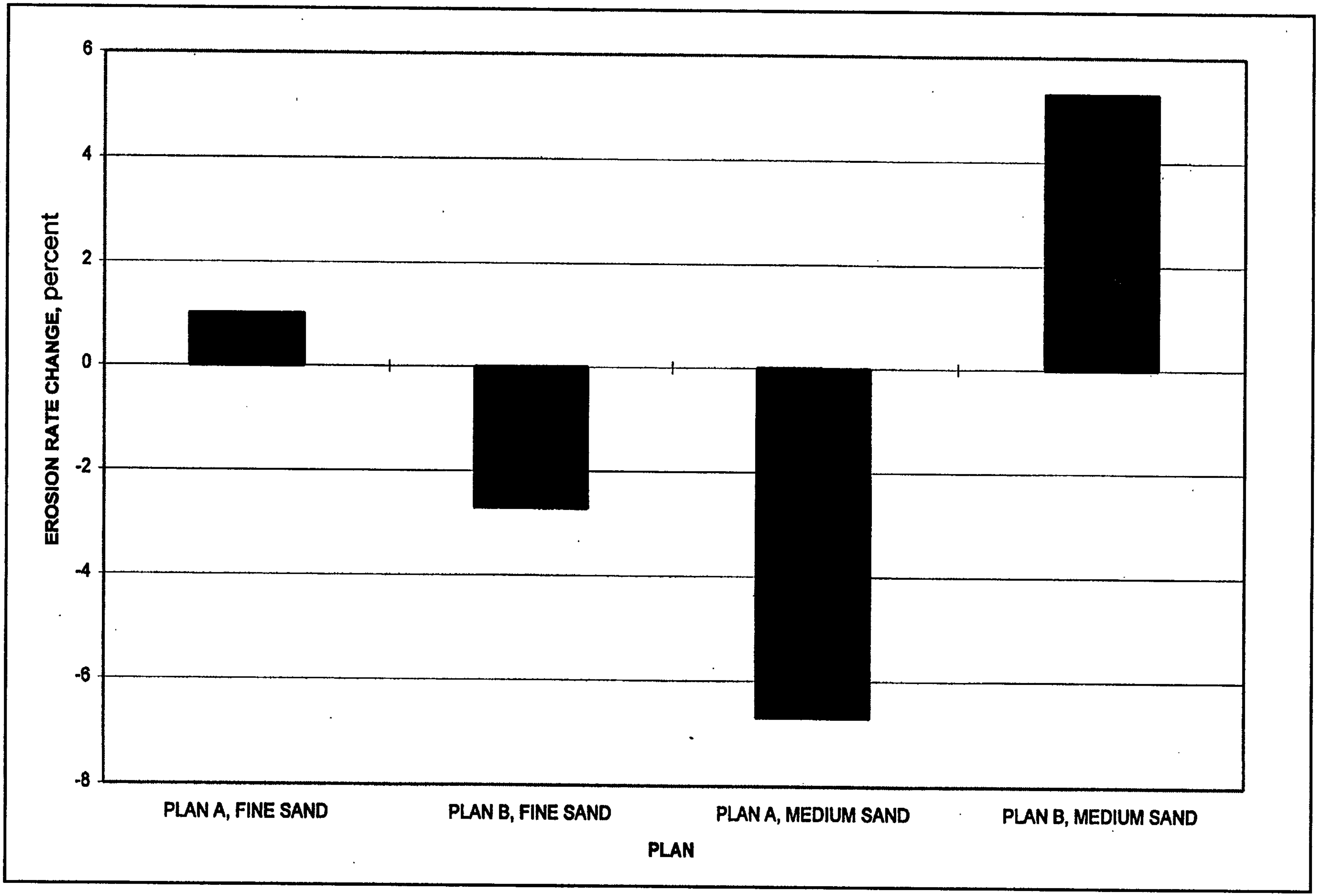

Figure A86. Change in deposition rate, Quarantine Island Upper Range (Northern Coastline)

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13.ABSTRACT ***(Maximum 200 words)***

The ship simulation study of St. Johns River, Jacksonville, Florida, included channel reaches from the outer entrance channel at the sea buoy to downtown Jacksonville, approximately 30 nautical miles. The study was performed to determine the effects of deepening the navigation channel from -38 ft msl to -42 ft msl. The proposed dredging would maintain the existing bank lines and bank slopes, extending the existing bank slope down to the deeper channel bottom, effectively reducing the channel width from 24 to 40 ft, dependent on the bank slope.

The initial plans examined were to deepen the entire channel without any widening and to deepen and widen the entire channel. Preliminary investigations conducted with pilots from the St. Johns Pilots Association indicated that the unwidened channel would not seriously impact navigation, except for two-way traffic. A third plan was developed that widened and deepened the channel reaches east of the Dames Point Bridge and only deepened the reaches west of the bridge, along with some realignments of reaches both east and west of the bridge. This plan, Plan C, was found to provide generally improved navigation as compared with the existing conditions.

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